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D8.5 - DEVELOPING DESIGN METHODS FOR NEW AND RETROFITTED BUILDINGS FOCUSING ON CITIZENS' HEALTH AND WELL-BEING – APPLICATION TO A REAL DEMO

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MULTICLIMACT

D8.5 – DEVELOPING DESIGN METHODS FOR NEW AND RETROFITTED BUILDINGS FOCUSING ON CITIZENS' HEALTH AND WELL-BEING – APPLICATION TO A REAL DEMO

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DoA	T8.5: Human-centred built environment design for improving people health and well-being– development for the application to a real demo case
Lead beneficiary	UKA
Main Authors	Mina Moayyedi, Rania Christoforou & Marcel Schweiker (UKA)
Main contributors	Gloria Cosoli (UNIVPM), Alessandra Mobili (UNIVPM), Valeria Leggieri (UNICAM), Lucia Barchetta (CAM), Marta Rivarola (RINA-C), Nensi Lalaj (BRC), Elena López Gunn (BRC), Maria de la cruz (BRC), Victoria Blessing (Steinbeis)
Reviewers	Nensi Lalaj (BRC), Celina Solari (RINA-C)
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3.0	20.09.2025	Final version as submitted

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Abbreviations and Acronyms

ACRONYM	DESCRIPTION
BIM	Building Information Modeling
BRC	Brigaid Connect
CAM	Comune di Camerino
CINEA	European Climate, Infrastructure, and Environment Executive Agency
EDA	Electrodermal Activity
EU	European Union
GDPR	General Data Protection Regulation
HVAC	Heating, Ventilation, and Air Conditioning
KPIs	Key Performance Indicators
LIS	Live Information System
MULTICLIMACT	MULTI-faceted CLIMate adaptation ACTions
PANAS	Positive and Negative Affect
PPG	Photoplethysmographic
RINA-C	RINA Consulting S.p.A.
STEINBEIS	Steinbeis Innovation GGMBH
UKA	Universitaetsklinikum Aachen
UNICAM	Università degli studi di Camerino
UNIVPM	Università Politecnica delle Marche
WHO	World Health Organization
WP	Work Package

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Executive Summary

This document serves as the Deliverable for Task 8.5, "Developing design methods for new and retrofitted buildings focusing on citizens' health and well-being – application to a real demo" within the MULTICLIMACT project, funded by the European Commission through CINEA, and led by UKA in collaboration with UNIVPM, UNICAM, CAM, RINA-C, BRC, and STEINBEIS.

The primary objective of this Task was to develop a comprehensive assessment framework for physical, mental, and social well-being, with a specific focus on its application in the Italian demonstration site, the Carmelitane building in Camerino. This task aimed to develop and adapt guidelines and tools previously defined in Task 2.5 for practical application in a real-world context.

In this task, guidelines were refined through a collaborative approach, integrating insights from existing frameworks, stakeholder engagement, health and resilience criteria, and the specific needs of the demonstration site. Key Performance Indicators (KPIs) from earlier project phases were used as the evaluation criteria, resulting in the selection of LEED v4.1 guidelines as the most suitable tool for the Italian demonstration site. A best-practice example was developed to address missing gaps in LEED, tailored to the unique challenges of the Carmelitane building, including seismic and heatwave risks, climate change, and cultural heritage aspects. This example provides a practical guide for future initiatives in similar contexts and remains broadly applicable. Additionally, the task involved developing and testing a study design incorporating both subjective and objective measures using the Live Information System (LIS) platform in preparation for WP11. This last point also included ensuring ethical and GDPR compliance.

In summary, Task 8.5 has successfully achieved its objectives through a collaborative and practical approach, setting a strong foundation for the next phases of the MULTICLIMACT project. A key highlight of this Task was its emphasis on human health and well-being, ensuring that the built environment not only enhances resilience but also promotes occupant well-being and satisfaction.

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1. INTRODUCTION

This report is a deliverable of the project "**MULTICLIMACT - MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales**", which is funded by the European Commission through the European Climate, Infrastructure and Environment Executive Agency (CINEA). MULTICLIMACT seeks to develop a comprehensive framework and toolkit to enhance the resilience of the built environment and its inhabitants against multiple natural and climatic hazards.

Within the MULTICLIMACT project, Task 8.5, titled "Human-centred built environment design for improving people health and well-being – development for the application to a real demo case" is led by UKA in collaboration with partners from STEINBEIS, BRC, RINA-C, UNIVPM, UNICAM, and CAM. It is part of Work Package 8, which is dedicated to developing design practices and methods for supporting natural hazard mitigation and sustainability across multiple scales (M13–M24).

Task 8.5 focuses on adapting and implementing guidelines and tools that were previously defined in Task 2.5 in a real-world context, specifically the Italian demonstration site, the Carmelitane building in Camerino in order to create a best-practice example for evaluating the impact of the environment on occupants' health and well-being. This task aims to translate theoretical planning and design methodologies into actionable practices to ensure that human-centered design principles are effectively applied to assess physical, mental, and social well-being in the built environments. The methodology includes refining existing guidelines and tools to the demonstration site, integrating Key Performance Indicators (KPIs) related to health and well-being to the guidelines, and developing a study design to assess potential subjective and objective measures for the evaluation of the effect of the environment on health and well-being. Part of this activity is to ensure the ethical and GDPR compliance of the study being conducted and the stakeholder engagement materials through co-creation processes.

This deliverable is structured into seven chapters. Chapter 1 introduces the background, objectives, target groups, and scope of Task 8.5, together with contributions of partners and interdependencies with other work packages. Chapter 2 provides the general background and context, including relevant outcomes from previous tasks and the design needs for the Italian demonstration site. Chapter 3 describes the methodology and development process, covering tool definition, KPI integration, study design, ethical and GDPR conformity measures, and the co-creation process. Chapter 4 presents the main results, such as the final guidelines for the demonstration site, study design implementation, compliance measures, and a best practice example. Chapter 5 highlights the outputs relevant to other work packages, while Chapter 6 provides the conclusions and lessons learned. Lastly, Chapter 7 lists the references, and the annexes include supporting material such as documentation, templates, and co-creation tools.

1.1. OBJECTIVES AND OUTCOMES

The specific objectives of T8.5 include:

- **Development of a comprehensive assessment framework for physical, mental, and social well-being** based on KPIs defined in the earlier project phase. This framework is tailored for application in the Italian demonstration site, providing a structured approach to evaluate how built environment designs impact human health across multiple dimensions. It uses pre-established KPIs to ensure consistency and measurability, forming the foundation for subsequent assessments.
- **Design of a robust study protocol incorporating subjective and objective evaluation measures**. This protocol aims to assess the effectiveness of the implemented designs by combining subjective data (e.g., occupant' multi-domain comfort and perception) with objective data (e.g., physiological and environmental measurements) as well as individual's

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physiological data (e.g., electrodermal activity (EDA) signal and skin temperature). This approach ensures a holistic evaluation of well-being outcomes.
- **Development of a best-practice example**. Based on the outcomes of the assessment framework and study protocol, this objective focuses on creating a best-practice example that demonstrates the successful application of human-centered design principles. This best-practice example will serve as a practical guide for future projects, showcasing effective strategies for improving health and well-being in similar contexts.
- **Ensuring ethical compliance and alignment with General Data Protection Regulation (GDPR) standards** across the study design.
- **Engaging stakeholders through co-creation processes** to refine and validate the solutions, fostering collaboration among experts and target groups.

Figure 1 below illustrates the objectives of this task and the corresponding activities and inputs.

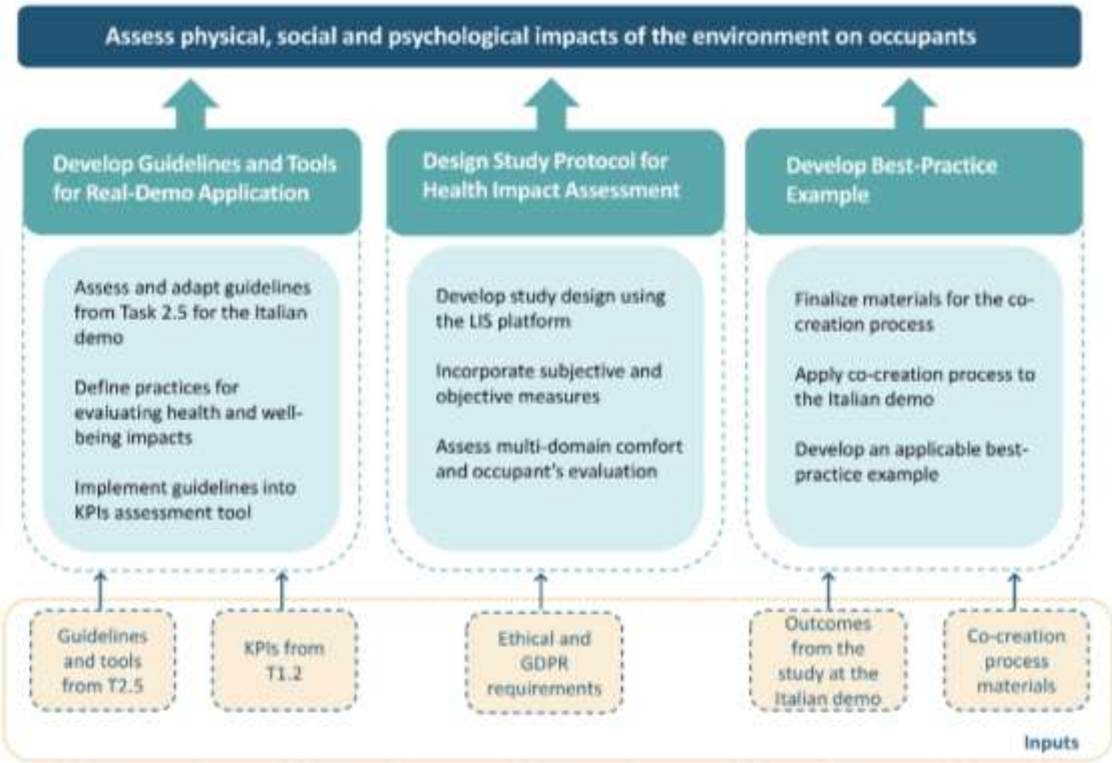

Figure 1. The main objectives of Task 8.5 with their supporting activities and inputs

1.2. TARGET GROUPS

The outcomes of Task 8.5 are intended to benefit a diverse range of stakeholders involved in planning, designing, and managing of built environments. The primary target groups include:

- **Policymakers**: At building scale, policymakers can use the guidelines and tools to inform building regulations that enhance health and well-being.
- **Public Administrations**: Project planners, health departments, and other administrative bodies can implement the tools in their projects to improve community resilience and well-being.
- **Architects, Designers, Urban planners, and Engineers**: Professionals in the design and construction sectors can apply the guidelines to create built environments that prioritize human health and resilience.

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- **Researchers and Academics**: Those studying the interaction of the built environment design and human health and well-being can build upon the task's findings and the developed study design to advance scientific knowledge.
- **Community Groups and Citizens**: Local communities and individuals can participate in co-creation processes and directly benefit from improved living environments.

These target groups ensure that the task's outcomes will be disseminated to the relevant stakeholders and that the outcomes implementation will be suitable to be applied across various scales and sectors.

1.3. TASK OUTLINE

To facilitate the work process of Task 8.5, the task has been divided into six subtasks, each addressing a specific aspect of the development and implementation process:

- **T8.5.1: Definition of Appropriate Tool for the Demonstration Site**
  This sub-activity involves adapting the guidelines and tools from Task 2.5 for practical application in the Italian demonstration site to ensure they are relevant to the local context. It lays the groundwork for the comprehensive assessment framework by customizing prior deliverables to local needs.
- **T8.5.2: Integration of Health and Well-Being Evaluation Criteria Based on KPIs**
  Incorporating KPIs and evaluation criteria into the design and assessment processes to quantify the impact on health and well-being. This activity directly supports the development of the comprehensive assessment framework by including measurable indicators of physical, mental, and social well-being.
- **T8.5.3: Study Design Implementation on LIS Platform**
  Implementing the study design in the LIS platform, by incorporating objective and subjective measures of health and well-being, and the environment.
- **T8.5.4: Ethical and GDPR Compliance Measures**
  Obtaining ethical and data management approval for the study to ensure compliance with ethical standards and GDPR policies.
- **T8.5.5: Co-creation Process Finalization and Application**
  Collecting and applying co-creation materials by engaging stakeholders in the development and implementation phases to ensure a co-creation process.
- **T8.5.6: Best-practice Example Development**
  Developing an example of best practice based on the Italian demonstration site and the task outcomes, to serve as a practical guide for future initiatives.

These subtasks ensure a systematic and comprehensive approach to achieving the task's objectives. The timeline of this task, categorized based on the subtasks, is presented in Figure 2 below.

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Figure 2. Timeline of the T8.5 and its subtasks

1.4. CONTRIBUTIONS OF PARTNERS

Table 1 shows the main contributions of the project partners in the tasks of T8.5, which reflect the relevant sections in this Deliverable.

PARTNER SHORT NAME	CONTRIBUTIONS					
	T8.5.1. Guidelines and Tool Adaptation for Real Practice	T8.5.2. Integration of KPIs and Health and Well-being Evaluation Criteria	T8.5.3. Study Design Implementation on LIS Platform	T8.5.4. Ethical and GDPR Compliance Review	T8.5.5. Co-creation Process Finalization and Application	T8.5.6. Best-practice Example Development
UKA	•	•	•	•	•	•
RINA-C		•			•	•
BRC		•				•
UNICAM	•			•		•
UNIVPM		•	•	•		•
CAM	•					•
STEINBEIS					•	

Table 1. Contributions of the partners

1.5. INTERDEPENDENCIES WITH OTHER WPS AND TASKS

Task 8.5 is interrelated with several other tasks within the MULTICLIMACT project. Specifically, it builds upon the guidelines and tools from Task 2.5 in Work Package 2, by adapting them for practical use in the Italian demonstration site. Additionally, the task incorporates KPIs related to building resilience and human health and well-being from Task 1.2 in Work Package 1, ensuring alignment with the overall evaluation criteria of the project. Moreover, it provides the materials needed for the

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implementation of the study at the Italian demonstration site, which will take place as part of WP11, such as tools and guidelines specifically adapted to the demonstration site, ethical approval and a ready-to-go platform, which will be used to assess environmental condition and human health and well-being parameters.

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2. GENERAL BACKGROUND AND CONTEXT

As previously mentioned, T8.5 builds directly upon the outcomes of Task 2.5 and focuses on the Italian demonstration site. Task 2.5 looked at evaluating and redefining tools and guidelines for both building and human resilience, with a particular emphasis on human health and well-being. The process involved a comprehensive assessment of existing building guidelines, followed by a redefinition phase to address identified gaps and improve applicability to the project demonstration sites.

To ensure a thorough and systematic approach, the evaluation process in Task 2.5 followed a structured methodology. Initially, 22 tools and guidelines were collected, but this number was reduced to 12 after excluding sources that were inaccessible or irrelevant to the building scale. The evaluation process incorporated analysis criteria aligned with KPIs from Task 1.2. These KPIs emphasize both human health and well-being, as well as building resilience.

Through a co-creation process with diverse stakeholders from science and practice, three key tools, including LEED Reference Guide for Building Design and Construction: LEED V4 Edition [8], WHO Report on Promoting Health While Mitigating Climate Change [59], and The Sustainable SITES Initiative (SITES) [60], were selected and refined. These guidelines were chosen based on their high relevance to the demonstration site aspects, including natural hazards (earthquake, flood, drought, and heatwaves), and building characteristics (cultural heritage) as well as a high inclusion of building and human KPIs.

The redefinition process aimed to integrate missing KPIs, expand applicability, and prioritize human-centric design principles. This approach aimed to develop guidelines that not only meet resilient building standards but also enhance occupant well-being and resilience. The redefined guidelines resulting from Task 2.5 incorporated several additional recommendations to address identified gaps in existing tools. Key topics addressed in the added recommendations included physiological and psychological adaptation, which were previously underrepresented in the evaluated tools. The guidelines also emphasized the importance of digital solutions and decarbonization strategies, as these were identified as potential indicators that were not sufficiently considered in existing resources. Furthermore, the recommendations were designed to strengthen the connection between building resilience and occupant well-being, particularly in the context of climate-related hazards such as earthquakes, floods, droughts, and heatwaves. The refined tools prioritized physical, mental, and social well-being through strategies like designing for health and comfort, integrating natural elements, and fostering social interactions [1].

The outputs of Task 2.5 provided a critical foundation for Task 8.5, enabling the practical application of these guidelines and developing resilient, sustainable buildings that enhance occupant health and well-being in the context of climate change. The redefined guidelines integrated specific examples from established guidelines that directly addressed both building and human KPIs. For instance, the LEED V4 Edition recommendations guided the incorporation of human-centric design strategies by emphasizing elements like designing for passive solar gains, natural ventilation, and the integration of natural elements such as plants and water features to enhance aesthetic appeal and occupant comfort. These strategies, along with recommendations for structural resilience like floodproofing and earthquake-resistant designs, laid a robust foundation for ensuring that buildings not only met resilient building guidelines and regulations but also promoted physiological and psychological well-being. This dual focus helped to bridge the gap in existing tools, ensuring that health and comfort were as prioritized as structural integrity.

In addition, the WHO Report on Promoting Health and the Sustainable SITES Initiative contributed critical recommendations that enriched the guidelines by addressing underrepresented areas such as psychological adaptation and digital solutions. Specific examples include guidelines for creating flexible spaces with natural lighting to improve mood and cognitive function, and strategies for risk avoidance that incorporated emergency response planning and maintenance protocols. These inputs were particularly useful in Task 2.5, as they provided a detailed roadmap for enhancing occupant well-being in the face of climate-related hazards. By emphasizing decarbonization, digital innovation, and the social aspects of design, such as fostering community interactions, the redefined guidelines successfully established a comprehensive framework for resilient, sustainable building practices.

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2.1. DESIGN NEEDS FOR THE CONTEXT OF ITALIAN DEMONSTRATION SITE

The Italian demonstration site selected within the MULTICLIMACT project is the *Ex Carmelitane* building, a historical structure located in Camerino and owned by the University of Camerino (UNICAM). Originally built in the late 19th century as a convent, the building now serves academic and innovation-related purposes, hosting offices, research laboratories, start-ups, and idea incubators. It develops across three floors and maintains its original sandstone masonry walls and timber floors, with brick partition walls and reinforced concrete used only in the staircase and roof structures. Despite the absence of heritage restrictions, the building preserves its visible masonry façades, excluding the possibility of external thermal insulation.

Strategically located in Camerino's historic core, on a ridge above two river valleys, and in proximity to university green spaces such as the Orto Botanico, the Carmelitane building functions as both a regional research hub and an urban demonstration site (Figure 3). Embedded in a compact, heritage-rich urban fabric, it anchors the university's presence in the town's social and spatial dynamics. As a locus for research, knowledge dissemination, and technology transfer, the building is not only technically important but also symbolically charged, reinforcing the university's role in regional innovation and civic identity.

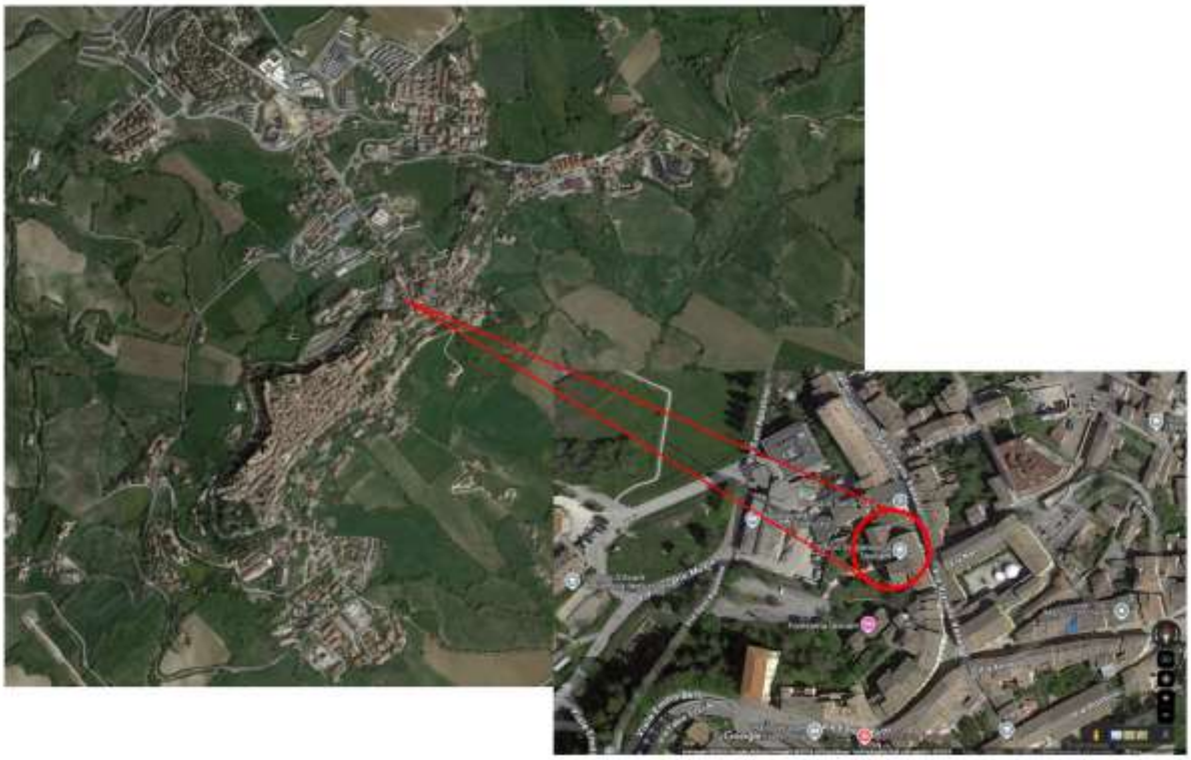

Figure 3. The location of Carmelitane building in Camerino, Italy

A structural consolidation intervention was carried out in 1989, including the reconstruction of internal spine walls, the addition of horizontal ring beams, and the replacement of floor structures. This intervention proved effective, as the building withstood the major earthquakes of 1997–1998 and 2016, confirming a high level of robustness in terms of structural resilience. The overall condition of the building remains good.

From an environmental perspective, the building is equipped with a traditional methane-powered radiator heating system. It lacks mechanical ventilation or cooling systems, relying instead on natural ventilation through widely distributed operable windows and external shutters. This configuration

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places greater importance on passive comfort strategies and occupant control over environmental conditions. Almost all internal spaces are daylit and ventilated, contributing positively to perceived indoor environmental quality.

Despite the absence of dedicated communal areas inside, the building benefits from a large outdoor green space which can support social interaction and psychological restoration. The indoor environment is typically calm and low-density, with occasional crowding in laboratories during operational peaks. The average daily occupancy is around ten people. Users can manage their immediate environment through openable windows and shading elements, which enhances individual behavioral adaptation capacity.

These site-specific features highlight key design needs for the implementation of the MULTICLIMACT framework. The Carmelitane building represents an interesting case where constraints related to heritage character, existing construction systems, and low-tech environmental control demand a nuanced approach to well-being assessment. The framework will be tailored to integrate subjective indicators (e.g., thermal and visual comfort perception, emotional resilience) with objective data collection (e.g., skin temperature, EDA, environmental sensors), aligning with project KPIs such as architectural and system resilience, passive autonomy, and adaptation mechanisms (e.g., physiological, psychological, behavioral, social).

In conclusion, the design needs for the Camerino context center on enhancing energy efficiency and occupant comfort while preserving the architectural and cultural heritage of historic buildings like the Ex Carmelitane. Any interventions must be compatible with the building's existing materials and character, ensuring that its historic value is preserved. This requires a balanced approach that integrates passive design strategies, such as natural ventilation and daylight optimization, together with reversible solutions, measures that can be removed or adapted without causing permanent alteration to the building fabric, addressing both sustainability and resilience without compromising the building's original identity. Figure 4 illustrates the functional distribution of spaces across floors (left), showing how offices, laboratories, and other uses are spread throughout the building, and the relevance of MULTICLIMACT KPIs per level (right), highlighting the prioritization of structural resilience, passive autonomy, and human adaptation across different floors. By tailoring retrofit measures to these unique constraints, the MULTICLIMACT framework aims to set a best-practice example for human-centered, sustainable upgrades in Mediterranean heritage settings.

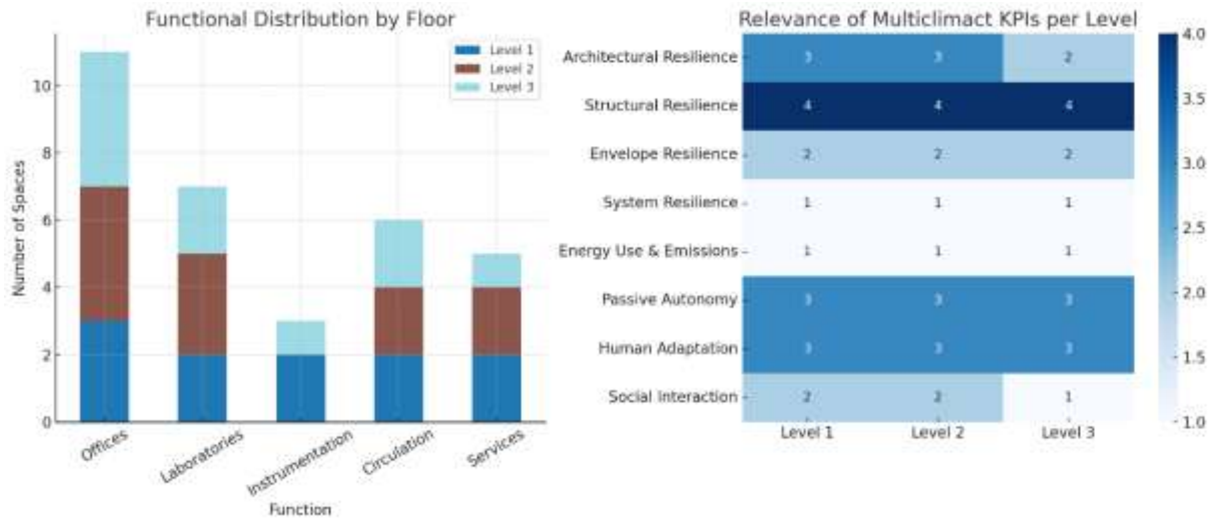

Figure 4. Functional distribution by floor (left), and relevance of MULTICLIMACT KPIs per level (right)

3. METHODOLOGY AND DEVELOPMENT

This chapter is dedicated to the presentation of the methodology developed for Task 8.5, which follows the main objectives of the MULTICLIMACT project, that include the emphasis on enhancing the resilience of the built environment and its occupants against multiple hazards while prioritizing human health and well-being. To support public stakeholders and citizens in assessing and improving the health and well-being impacts of built environment designs, particularly within the context of the Italian demonstration site, the methodology adopted for Task 8.5 encompasses the subsections shown in Figure 5 and further detailed in the following sub-sections.

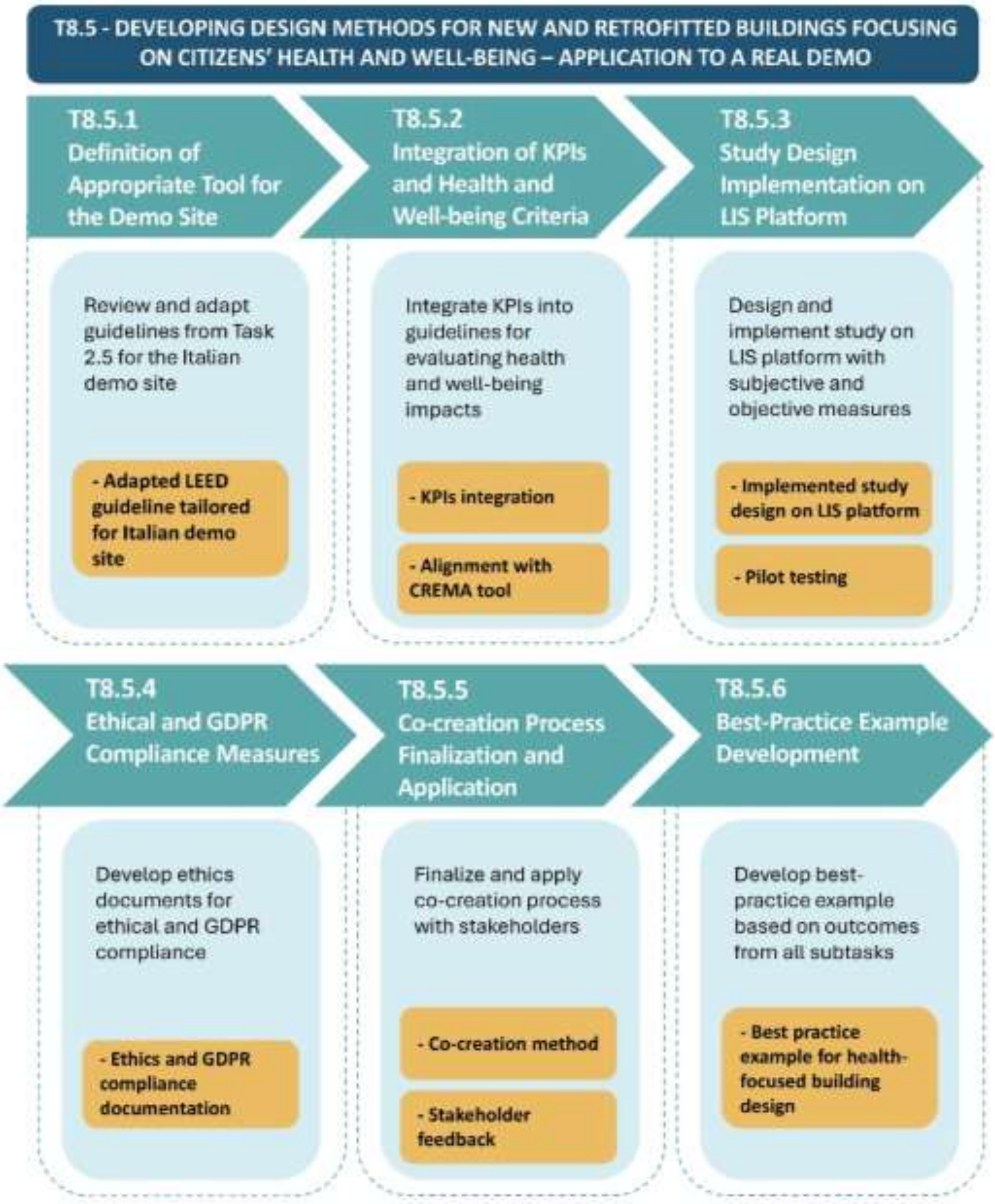

Figure 5. Overview of the methodology developed for T8.5

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3.1. DEFINITION OF APPROPRIATE TOOL FOR THE BUILT ENVIRONMENT OF THE DEMONSTRATION SITE

The initial phase of the methodology focused on identifying an appropriate tool to be adapted to the Italian demonstration site. This step was critical to ensure the tool selected could be made context specific. The process began with a detailed review of the tools and guidelines previously gathered in Task 2.5. First, the resources were evaluated based on their performance against the Key Performance Indicators (KPIs) from Task 1.2 and rated using a binary scoring system.
Second, to tailor the selection to the Italian context, particular emphasis was placed on the hazard profile of the demonstration site, which is primarily exposed to earthquakes and heatwaves (see Annex A). By integrating both performance-based evaluation and hazard relevance, this process ensured that the selected tool makes an ideal foundation for the Italian demonstration site, where these hazards pose significant challenges.

3.2. INTEGRATION OF CORRECT EVALUATION OF HEALTH AND WELL-BEING BASED ON KPIS IN GUIDELINES

Once the appropriate guidelines had been selected, a robust evaluation framework for health and well-being, based on KPIs was integrated. This step ensured that the guidelines comprehensively assess the impacts of the built environment on its occupants, aligning with the MULTICLIMACT project's objectives and their emphasis on human health and well-being.

An Excel sheet was developed to facilitate contributions from multiple stakeholders on what is missing in terms of health and well-being KPIs. UKA took the lead in identifying KPIs absent from the selected tool (LEED guidelines) but applicable to the demonstration site, providing recommendations to address these gaps. This step ensured that the guidelines holistically addressed both human and building KPIs relevant to the demonstration site.

To broaden the scope, partners were invited to contribute additional ideas or design practices, regardless of their inclusion in the redefined LEED guidelines, fostering an inclusive framework. Meanwhile, RINA-C, the coordinator and responsible for developing the CREMA tool, has done an assessment between the LEED guidelines and the CREMA tool in parallel. The partners identified any missing aspects for each KPI and suggested enhancements to ensure alignment and completeness. This multi-partner collaboration ensured that the guidelines were enriched with diverse expertise and harmonized across the project's tools, resulting in a more valuable and realistic best-practice example.

3.3. FURTHER DEVELOPMENT OF SELECTED GUIDELINES FOR THE DEMONSTRATION SITE

The methodology of this sub-task involved the refining and tailoring of the LEED guidelines to the specific context of the Italian demonstration site, the Carmelitane building in Camerino, to ensure its practical applicability and effectiveness.

To do so, demo leaders were asked to provide comments and examples on how LEED's design practices could be implemented within the demonstration site's context. They were also encouraged to propose additional aspects that are not currently applied to the building but could be integrated through the project. Furthermore, to collect user perspectives and occupant experiences related to their health and well-being, preliminary data was collected via the LIS platform before the actual implementation of the study in the demonstration site. This preliminary data collection was part of the co-creation process in this task activity. Based on the results of this activity and health and well-being criteria evaluation results, the LEED guidelines were redefined and developed to form a best-practice example on a building scale.

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3.4. DEVELOPMENT OF STUDY DESIGN & IMPLEMENTATION INTO LIS PLATFORM

3.4.1. SUBJECTIVE & OBJECTIVE MEASURES FOR SHORT AND LONG-TERM EFFECTS

UNIVPM and UKA designed a test protocol to assess the multidomain comfort in indoor environments. Specifically, the protocol is intended to be implemented in the Italian pilot, carrying out the tests in rooms for office use. Multidomain parameters need to be measured to provide an insight into the overall comfort of people; in particular, environmental and physiological sensors are foreseen to gather information on the whole ecosystem, including the building as well as its occupants. Also, surveys on the perceived comfort are administered to the participants at regular intervals.

Specifically, the main objective was to develop a methodology to measure holistically people's well-being in the built environment using wearable physiological sensors and environmental sensors, while assessing the subjective experience of the occupants via *ad hoc* developed questionnaires. The test protocol foresees exposing the participants to different thermal conditions typical of different seasons (namely summer and winter). Participants will be asked to fill out questionnaires regarding their thermal perception and comfort and their emotional state, while their physiological signals (i.e., photoplethysmographic – PPG - signal, electrodermal activity– EDA - signal, skin temperature, and movement related signals) are acquired. Then, data will be analyzed in correlation with the assessed environmental parameters as well as with the results from surveys. It is worth to underline the fact that all the data (both from sensors and from surveys) are integrated in the LIS platform, developed within the framework of the MULTICLIMACT project by the partner LIS, and is based on the BIM of the pilot building in Camerino, Italy.

These results are potentially relevant for both well-being optimization and productivity enhancement in the built environment as well as for improving the buildings' energy efficiency and making the whole ecosystem more resilient towards extreme natural events such as heatwaves.

The test design includes the recruitment of 30 voluntary participants (aged ≥18) for the study. While this number is quite limited, it is sufficient for this type of pilot study with the objective of validating the proposed methodology in a field study setting.

The acquisition systems and methodologies include the following:

- Emotibit [2], a multidomain wearable sensor (a smart band) capable of collecting EDA signal, skin temperature, PPG signal, humidity and temperature, and motion-related signals (through a gyroscope, an accelerometer, and a magnetometer).
- DomX sensor (DomX IoT technologies, Thessaloniki, Greece), which is a multidomain environmental measurement system including sensors for indoor environmental quality assessment including air temperature (°C), relative humidity (%), atmospheric pressure (Pa), PM1, PM2.5, and PM10 (μg/m^3), CO_2 (ppm), breath VOCs (ppm), and illuminance (lux).
- Questionnaires on demographic and personal information, multidomain comfort, Positive and Negative Affect (PANAS), and clothing level.

The whole study is coordinated through the LIS platform thanks to the previous implementation in such a digital system, allowing not only to administer surveys but also to collect and synchronize all the data, also from different sensors and gathered in multi-resident scenarios (up to four participants can be monitored simultaneously).

The wearable sensors will be worn on the non-dominant wrist of participants. The environmental sensors will be installed in a unique position in the room close to the environment experienced by the participants (i.e., on a desk). Also, to evaluate the effect of an insulation panel based on a multifunctional mortar (patented by UNIVPM [3]) aiming at improving the IEQ of indoor environments, the tests will be performed in two "twin" rooms, located at the 1st floor of Carmelitane building, Camerino, Italy (Figure 6). Within the framework of these tests, both rooms are offices, where a user usually remains for several hours.

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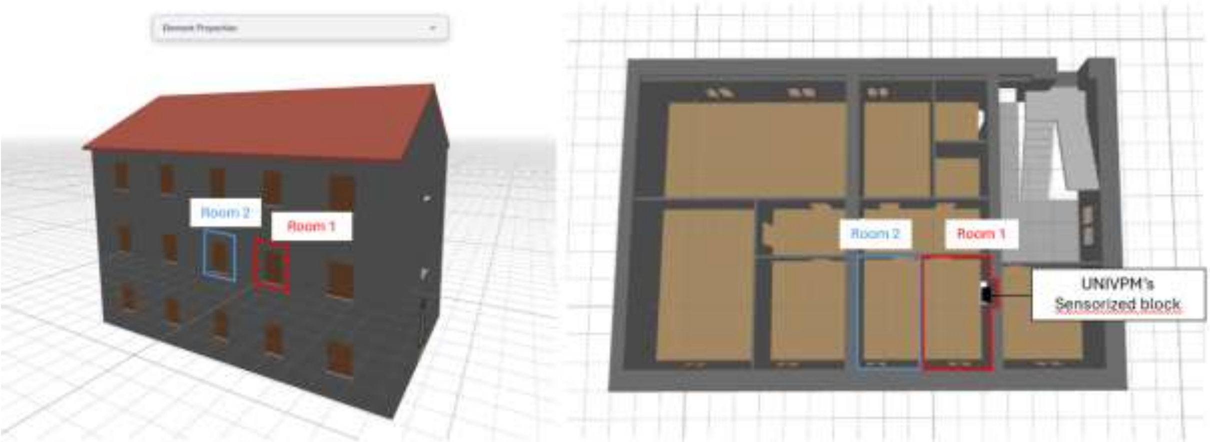

Figure 6. Layout of the two twin rooms on the 1st floor of the Carmelitane building, used for testing

A test session will have a duration of approximately 90 minutes, during which the participant will be allowed to freely choose the activity to be performed. The activity is regularly annotated on a dedicated questionnaire administered regularly (every 15 minutes after the completion of the previous one – the first one is administered 15 minutes after the beginning of the test). These questionnaires are administered according to a 5-points for multidomain sensation as well as for multidomain preference and satisfaction and affect. The results provide indices of multidomain perception and comfort. Indeed, the test is intended to monitor participants during their usual activities in the room, without deliberately altering the environmental conditions of the room. The participants will be asked to bring with them their own laptop to work or a book to read as they would normally do on a usual working day. Normal ventilation operations (e.g., window opening) will be allowed as well as the use of personal comfort tools (e.g., space heaters/fans, depending on the season).

The acquired data will be processed using both algorithms embedded in the acquiring platform and other ones developed in the MATLAB/Python environment. The aim of the processing is to correlate physiological quantities to environmental parameters as well as to surveys results. The final objective is to synthetize indices related to the participants' well-being and health. Also, Artificial Intelligence/Machine Learning techniques, and existing thermo-physiological models could be applied to do this. Moreover, these methods can be applied also for predictive purposes concerning different quantities, both environmental (e.g., temperature and relative humidity) and subjective parameters (e.g., heart rate or health/well-being indices). This information can be exploited for the thermo-hygrometric control of the built environment, with the objective of optimizing both the participants' well-being and the building energy consumption. Additionally, the health and well-being indices will be used to enrich the buildings' BIM-system. The implementation of the whole experimental test campaign is described in [4].

3.5. ETHICAL & GDPR CONFORMITY MEASURES

When designing the experimental test protocol to be implemented in the Italian pilot, the involved partners thoroughly considered aspects related to ethics and data management. In particular, an informed consent module was prepared to describe in detail the methodology adopted and the aims of the study to the participants of the study. Also, the partners prepared detailed documentation to ask for the ethical approval of the study. The documents included test protocol (and the surveys administered to the participants along with the tests), informed consent form, and specific justifications for the choices made in terms of equipment, sensors, surveys, etc. All data collected

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via the wearables, environmental sensors, and questionnaires, as well as any participant-related information handled through the BIM platform, are managed in compliance with GDPR, ensuring secure storage and anonymization of personal and physiological information.

3.5.1. REQUEST TO THE ETHICS COMMITTEE

The University of Camerino Research Ethics Committee was established by Rectoral Decree No. 425/2024 on 08/08/2024. The Committee operates with the aim of safeguarding, in compliance with current regulations, the rights, dignity, integrity, and well-being of human beings involved in research projects.

The Committee is responsible for providing reasonable opinions on research projects involving human participants, in order to ensure compliance with the ethical principles defined by national, European, and international regulations. The Research Ethics Committee of the University of Camerino bases its work on the principles of interdisciplinarity, competence, and independence.

The Ethics Committee operates in compliance with current regulations and provides opinions on research projects submitted by the University's faculty, researchers, research fellows, and doctoral students, with the aim of ensuring:

a) the protection of the rights, dignity, integrity, and well-being of human beings involved in the research under evaluation;

b) the respect and protection of all other living organisms;

c) the freedom of research and the promotion of science;

d) the respect and safeguarding of the environment from a sustainability perspective;

e) the social sustainability of research; and

f) the compatibility of research with the principles of the Constitution, Italian and European legislation, international law, the protection of human rights, and the promotion of peace and cooperation among peoples.

The required documentation submitted to the Committee includes (see Annex D):

1. Request for Opinion – Form 1;
2. Information Sheet – Form 2;
3. Privacy Notice Regarding the Processing of Personal Data – Form 3;
4. Detailed Protocol of the Proposed Research – Form 4; and
5. Recent CV of the Principal Investigator.

The request for an opinion from the Ethics Committee of the University of Camerino regarding the tests to be carried out in T11.1 and T15.1, in accordance with the procedures developed in T8.5, has been submitted by the UNICAM research group. In order to support UNICAM in the request, all the partners involved in T8.5 contributed to the preparation of several documents, in particular:

- Informed consent form (described in Section 3.5.2, see Annex B).
- Test protocol (described in Section 3.4).
- Surveying methodology (see Annex C).

The prepared documentation has been incorporated into the official request forms, which must be submitted in Italian. These forms must also include a general description of the project, the partners involved, etc., in accordance with the regulations of the Ethics Committee (https://www.unicam.it/sites/default/files/regolamenti/REGOLAMENTO_COMITATOETICO_02122024%20per%20pubblicaz.pdf).

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3.5.2. INFORMED CONSENT FORM

The informed consent module includes sections related to the campaign, the main objective of the study, the detailed test protocol and the data processing pipeline. Data acquisition systems and related data collected are listed for the sake of clarity. The procedure for data acquisition is described and the operator will also verbally explain to the participants the objective, the adopted methodology, and the test procedure.

Finally, aspects related to risks (not present) and privacy issues are reported. When signing the form, the participant is asked to report demographic information; all the data is managed to preserve the privacy of the participant. In particular, all the data will be kept confidential and no personal information will be preserved.

The participation is voluntary, and the participants can exit from the tests at any time, without any justifications, and without any consequences at all.

3.6. CO-CREATION PROCESS & BEST PRACTICE EXAMPLE

To ensure more effective and inclusive outcomes, co-creation to deal with aspects of health and well-being might enhance the strategies applied and improve the predicted impacts of the tools and guidelines. Therefore, emphasis was placed on the co-creation process throughout the activities of this task. Co-creation is especially relevant for creating social innovation, as it is often driven by the cooperation of heterogeneous stakeholders [5]. For the field of social innovation especially, stakeholders from diverse sectoral contexts are key for finding suitable solutions. These stakeholders have a common interest in certain problems but very different approaches to tackling them, often speak different professional languages and have usually had little prior contact with each other before. To foster such innovations, it is essential to establish strategic methods that enable effective collaboration among stakeholders. Facilitators play a key role by creating environments where otherwise disconnected actors can engage, exchange perspectives, and co-create. Within the Quadruple helix approach, this can be demonstrated through pilot cases or real-life fairs that showcase and validate the functionality of emerging innovations. According to the concept of the Quadruple helix [6] for innovation, stakeholders should come from academia, industry, and public, something that was initiated in Task 2.5 and further implemented within this Task 8.5. As the focus here is co-creating social innovations, it makes sense to focus on co-production at different stages of planning, design, and implementation of the guidelines suggested. This was mentioned above as one of the kinds of co-creation processes that were emphasized in this activity. To support these different stages, different tools were necessary. Based on tools available for innovation management generally, Steinbeis has adapted and selected tools suitable to support the creation of social innovations and published them in a toolkit [7]. Therefore, to tackle this, various stakeholders were involved in understanding the concept of building and human resilience and then of the constructs of health and well-being, which are the focus of this activity. Finally, the implementation is planned, including developing an implementation plan and identifying missing expertise. This step was implemented during the integration of partner expertise in adopting LEED guidelines for the Italian demo and redefining them to include all aspects of health and resilience relevant to the context. Different tools are set out in the toolkit for each stage, to be selected according to the most benefit it can bring to the social innovation to be developed. Partners collaborated in forming the LIS platform as the main tool for designing and conducting the study. The tools helped the moderation work done by the facilitators, in this case from UKA, as could thus also support the co-creation for designing buildings to promote health and well-being. This included the preliminary data collection of occupants' perspectives.

Finally, based on the demonstration site features and the task outcomes, the co-creation process enabled the development of a best practice example to serve as a practical guide. Specifically, the aim was to demonstrate the successful application of human-centered design principles and to use the best-practice example as a guide for future projects, showcasing effective strategies for enhancing health and well-being in similar contexts. The best practice example incorporated

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additional key-criteria reflecting input from all partners, addressing gaps in LEED and reflecting on Camerino's context. This multi-partner collaboration ensures that the best practice example is enriched with diverse expertise, resulting in it being more valuable and realistic.

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4. RESULTS

4.1. DEFINITION OF APPROPRIATE TOOL FOR THE DEMONSTRATION SITE

Subtask T8.5.1 presents the results of the review process for selecting the appropriate tool in the context of the Italian demonstration site, with a specific focus on building-scale tools. This review evaluated the guidelines performance against KPIs and their relevance to the main hazards identified for the Italian site including earthquakes and heatwaves (see Annex A).

Among all 12 reviewed tools and guidelines, the **LEED v4.1** guidelines [8] were identified as the most suitable option for further development. The LEED stood out as the only guidelines that address both earthquakes and heatwaves at the building scale, while also incorporating KPIs that assess building resilience along with human health and well-being (Figure 7).

The LEED v4.1 guidelines will be further developed in the following sections in order to tailor it specifically to the Carmelitane building context, ensuring it fully reflects the local challenges and considerations.

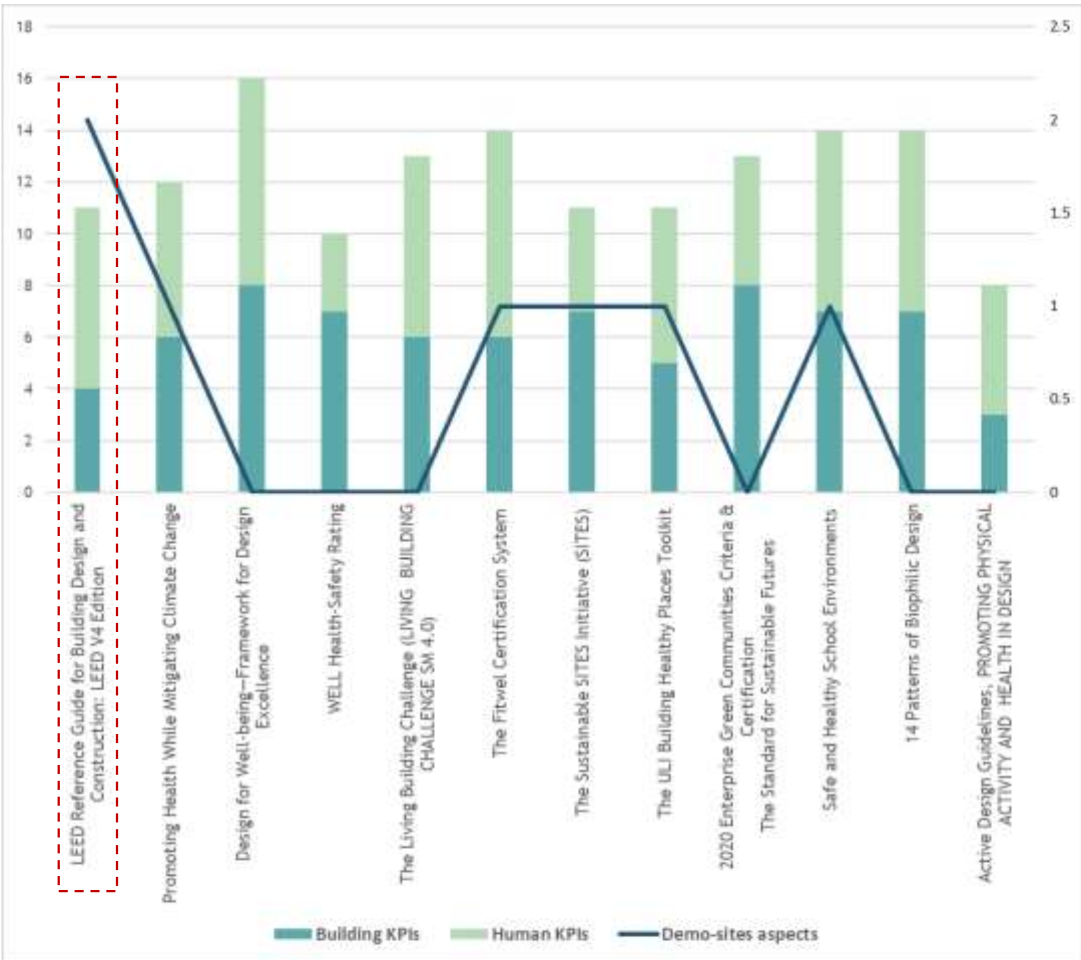

Figure 7. Evaluation of tools for the Italian demonstration site: LEED v4.1 as the optimal choice for resilience and well-being

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4.2. INTEGRATION OF HEALTH AND WELL-BEING EVALUATION CRITERIA BASED ON KPIS

Subtask T8.5.2 presents the results of KPI-based integration activity aimed to align LEED v4.1 [8] with health and well-being criteria. Through a collaborative co-creation effort, partners added design practices and recommendations to be included in the LEED guidelines, based on their fields of expertise and identified gaps in terms of health and resilience KPIs. Table 2 summarizes the recommendations suggested by partners against each KPI group, along with an assessment of current LEED–CREMA tool compatibility.

Results showed that in the building resilience KPIs, such as architectural resilience, envelope resilience, structural resilience, and system resilience, innovative strategies including passive solar optimization, self-healing materials, double-skin facades, seismic base isolation, and smart thermal zoning, were initially missing from existing LEED guidelines and consequently added by partners for inclusion. However, these recommended measures were assessed and showed no CREMA tool compatibility. Similarly, energy-use and carbon-emission KPIs (e.g., phase-change materials, embodied-carbon assessments, on-site renewables, etc.), risk avoidance (e.g., emergency planning), and maintenance (e.g., self-cleaning materials) were recognized as essential to mitigate climate impact but lacked corresponding practices in the current LEED framework. However, when assessed against the CREMA tool, many of these suggestions show no alignment, marked as no match.

The term "No match between LEED guidelines and the CREMA tool" indicates that certain LEED v4.1 design practices related to health and well-being are not yet reflected in the CREMA framework. This gap arises from the tool's current scope and metrics, which do not fully account for these practices. However, the CREMA tool has the potential to evolve as a flexible framework, and future updates could integrate these criteria to better align with LEED guidelines.

Further gaps were identified in the human-centric KPIs. Behavioral adaptation measures (such as operable windows, personalized thermal controls), physiological and psychological adaptation features (like biophilic elements, natural lighting, etc.), and satisfaction metrics (occupants' surveys and universal design) were all relevant but remain under-represented in LEED guidelines. Other human-centric KPIs, such as perceived air quality (e.g., IAQ sensors), thermal comfort (e.g., personal comfort systems), and acoustics comfort (e.g., sound insulation), further illustrate this gap.

This multi-partner validation process, including feedback from UNIVPM, BRC, UKA, RINA-C and demonstration site stakeholders, ensured that the final guidelines will address these gaps. By implementing these recommendations, the redefined LEED guidelines can better support health and well-being of occupants, providing a practical and resilient framework for the built environment.

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KPIS	DESIGN PRACTICES & RECOMMENDATIONS BY PARTNERS	COMPATIBILITY BETWEEN THE LEED GUIDELINES AND CREMA TOOL
Architectural resilience	- Design of the building form: consideration of surface to volume ratio (S/V) during the design process. - Adapting regulations considering both U-Values and S/V ratios according to climatic zone and its needs. - Optimize the building's orientation and shape to maximize passive solar gains and natural ventilation. - Use aerodynamic shape optimization techniques in tall buildings to reduce wind loads. - Integrate active design elements such as centrally located staircases with natural light and attractive finishes to encourage physical activity. - Ensure all buildings are accessible with no steps with a universal design. - Incorporate elements such as plants, water features, and windows to enhance the overall aesthetic of buildings. - Employ durable and sustainable materials that make the buildings safer and able to self-heal as well as self-perceive their own health status.	No match between LEED guidelines and the CREMA tool!
Structural resilience	- Conduct floodproofing of lower floors, including perimeter floodproofing (barriers/shields). - Design and install building systems as specified by the full criterion so that the operation of those systems will not be grossly affected in case of a flood. - Mitigate coastal flooding by providing a physical buffer against waves and storm surges. - Design structures with redundancy and ductility to allow for redistribution load in case of localized damage. - Design new and retrofit buildings to follow the standard criteria for Earthquake Resistant Buildings. - Implement capacity design principles to ensure ductile failure modes in critical elements. - Include expansion joints in concrete structures to accommodate thermal expansion during heatwaves, preventing cracking or structural damage. - Reinforce foundational systems and structural elements to prevent failure during unexpected events.	No match between LEED guidelines and the CREMA tool!

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	- Consider redundant design strategies for critical infrastructure, erosion-resistant foundations and structures, and seismic and extreme load-resistant design. - Use of flexible structural connections in order to Improves resilience. - Reinforce structural cores by using reinforced concrete walls in the building's center to enhance resistance against lateral loads from wind or earthquakes. - Use of seismically isolated columns by employing elastomeric bearings and friction isolators in foundations to reduce the impact of seismic movements.	
Envelope resilience	- Use of double-skin facades that regulate temperature and optimize energy performance. - Employ recycled and low-impact materials which are compatible with Building Product Disclosure. - Incorporation of advanced thermal insulation to improve efficiency of buildings. - Consider self-healing materials such as smart materials that after damage, defects, cuts, or fractures, can return to their original state by triggering self-repair (e.g., concrete with calcifying bacteria that seal cracks, extending structural lifespan). - Use of high-reflectance materials to minimize heat absorption. - Design of building envelopes resistant to hurricanes or earthquakes to increase durability. - Employ kinetic facades by using movable panels that adjust their position based on wind direction and solar radiation to enhance energy efficiency and reduce storm impact. - Employ thermal transition glass by using electrochromic or thermochromic materials that adjust transparency to minimize thermal load.	No match between LEED guidelines and the CREMA tool!
System resilience	- Encourage thermal zoning and smart control systems that adjust cooling based on occupancy and external temperatures. - Recommend the integration of active or passive seismic protection systems, such as base isolators or tuned mass dampers, especially in seismic-prone regions. - Include provisions for water filtration or UV sterilization systems where contamination risk is high.	Missing in the LEED guidelines: 1. Refrigerant Management: Select refrigerants that are used in heating, ventilating, air-conditioning, and refrigeration (HVAC&R) equipment to minimize or eliminate the emission of compounds that contribute to ozone depletion and climate change. 2. Grid Harmonization: The intent is to encourage participation in demand response programs to enhance energy system efficiency, reduce costs, improve grid reliability, and lower greenhouse gas emissions. Projects must assess building

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		systems for demand response participation, excluding on-site electricity generation. Participate and include the DR processes in the current facilities requirements and operations and maintenance plan. Analyze the building's annual load shape and peak load based on metered electricity use and electric utility bills.
Energy use and carbon emissions	- Include PCMs (Phase Change Materials) to store thermal energy, release/absorb sufficient energy, and provide useful heating/cooling capabilities. - Consider using recycled sustainable materials with low carbon footprint such as CO_2-capturing concrete and bio-based insulation. - Require the calculation of operational carbon emissions and encourage embodied carbon assessments in building materials and construction processes. - Design ventilated and shaded facades to reduce overheating and optimize energy performance. - Recommend incorporating on-site renewable energy systems, such as solar PV panels or solar thermal collectors, with incentives or LEED credit eligibility. - Use of high-albedo reflective roofs by using white roofs or materials with solar-reflective properties to reduce the urban heat island effect.	No match between LEED guidelines and the CREMA tool!
Blue and green infrastructures	- Include provisions for green roofs and vertical greening systems to enhance building envelope performance and biodiversity. - Employ rainwater harvesting and reuse water for landscaping. - Encourage planting of native and drought-tolerant species to reduce water demand and improve local ecosystem integration.	Missing in the LEED guidelines: Irrigation: Irrigate vegetation only with automatic controlled systems utilizing either rain shutoff, moisture sensing or weather-based controls.
Passive autonomy	- Create floor plates and spatial volumes that facilitate daylight from above and/or the side. - Use light shelves, skylights, or solar tubes to bring daylight deeper into the building. - Control for solar heat gain, optimizing insulation, spacing windows and fans evenly, limiting occupied spaces over unheated spaces, and avoiding thermal bridges. - Use thermal mass floors or walls to absorb and slowly release solar heat. - Employ finishings able to regulate IAQ and other environmental parameters.	Missing in the LEED guidelines: Indoor air quality: Minimum opening location and size requirements for naturally ventilated spaces: 1) maximum distance from operable openings: - 2 x ceiling height for single side distance, - 5 x ceiling height for double side opening,

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	- Design for effective cross-ventilation to promote air movement without mechanical systems and incorporate operable windows or roof vents to allow for manual control of airflow. - Maximize bioclimatic design to reduce energy demand.	- 5 x ceiling height for corner opening (along a line drawn between the two openings that are the farthest apart. For floor area outside line, comply with single side opening). 2) minimum opening area: 4% of floor area (for single side opening, double side opening and corner opening).
Risk avoidance	- Consider emergency response and recovery plans to manage the impact of natural hazards when they occur. These plans may include evacuation procedures, emergency shelters, and support services for affected residents. - Emergency preparedness planning in health facilities or general public facilities. - Incorporate structural monitoring systems to enable real-time performance supervision. - Design monitoring systems are able to regularly provide data related to the structural health of the building, so as to timely intervene when certain thresholds are overcome. - Exploit monitored data to generate early warnings; define consequent emergency plans. - Identify a minimum of one potential emergency scenario within the geographic region. - Identify emergency resources that will be kept on site for the identified emergency scenario(s). - Establish an emergency response team(s). - Provide an automated emergency address notification system. That system decreases the time it takes occupants to respond to emergencies, contributing to enhanced safety and reduced absenteeism.	No match between LEED guidelines and the CREMA tool!
Maintenance	- Ensure that adequate financing is made available to increase resilience to the health impacts of climate change. - Assess and maintain air treatment systems and other HVAC systems. - Management plans (e.g. moisture management plan) for building operations that contain a system for occupants and tenants to notify the building management about possible problems and damage, as well as a schedule of periodic inspections for signs and potential sources of damage (e.g. discoloration, molding on the ceilings, walls, and HVAC equipment). - Plan interventions considering the regularly monitored data on the building.	No match between LEED guidelines and the CREMA tool!

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	- Foster collaboration between different teams to ensure that maintenance strategies are aligned with the overall building's performance goals and sustainability targets. - Design of accessible spaces to facilitate efficient maintenance which reduces operational costs. - Employ walkable roofs with full accessibility to facilitate inspection and repair of upper installations. - Use self-cleaning coatings that foster hydrophobic and photocatalytic materials to reduce dirt accumulation.	
Physiological adaptation	- Design spaces and furniture to support health and reduce fatigue and avoid constant physiological strain. - Design lighting systems that mimic natural daylight to regulate sleep patterns and mood to overcome potential mitigation strategies (e.g. closing curtains in the morning to reduce heat inside the house) - Maintain temperature, humidity, and air quality within ranges that promote healthy respiration and thermoregulation. - Encourage physical activity and exercise in space design to support physical health and reduce the risk of obesity, diabetes, etc. - Consider the visual connection with nature for relaxation of body and mind (i.e. muscles, as well as lowering diastolic blood pressure and stress hormone). - Use temporal and spatial changes in temperature, light, colors and textures to encourage pleasure within space.	No match between LEED guidelines and the CREMA tool!
Psychological adaptation	- Control indoor environmental parameters according to the individual perception of multidomain comfort, so as to achieve personalized comfort solutions. - Incorporate natural elements like plants, water features, and natural light to reduce stress and improve mood. - Create flexible spaces that can be adapted to different needs and preferences. - Provide natural light and ventilation to improve mood and cognitive function. - Promote physical activity and exercise in space design to support mental well-being by reducing stress and feelings of depression and anxiety. - Including spaces that offer varying levels of stimulation and privacy to cater to different psychological needs.	No match between LEED guidelines and the CREMA tool!

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Behavioral adaptation	- Ensure occupants have access to operable windows, adjustable blinds/shading, and localized lighting systems to personalize their environment. - Install zoned HVAC systems or individual thermostats in shared spaces to allow users to adjust thermal conditions to their comfort. - Include flexible-use spaces that adapt to varying activities and preferences, allowing users to move to areas with more desirable conditions.	No match between LEED guidelines and the CREMA tool!
Social adaptation	- Promote social capital and combat loneliness by creating both interior and exterior arrangements that encourage positive informal social interaction among neighbors, acquaintances, and associates. - Provide spatial features that support visual and acoustic privacy but allow opportunities for informal encounters. - Use universal design principles so that the entire community of users will feel included, welcome and comfortable.	No match between LEED guidelines and the CREMA tool!
Satisfaction	- Enable user control over environmental conditions (e.g., lighting, temperature, airflow) to increase perceived satisfaction and reduce complaints. - Implement regular satisfaction surveys to assess users' feedback and expectations.	No match between LEED guidelines and the CREMA tool!
Privacy & safety	- Include clear signage and evacuation plans to enhance emergency preparedness. - Ensure adequate lighting in entrances, corridors, and outdoor areas to improve safety and reduce perceived risks.	No match between LEED guidelines and the CREMA tool!
Perceived Air quality	- Install real-time IAQ sensors to track pollutants (CO_2, VOCs, PM2.5) and display results in public areas. - Suggest windows opening/closing actions on the basis of the measured IAQ. - Use finishes and furnishings that emit minimal VOCs and adhere to green product certifications.	No match between LEED guidelines and the CREMA tool!
Acoustics comfort	- Employ materials to improve acoustic insulation if noisy environments are present close to the building. - Separate quiet zones (offices, reading rooms) from noisy areas (lobbies, cafeterias) through layout planning and sound insulation. - Install double-glazed windows to minimize sound transmission.	No match between LEED guidelines and the CREMA tool!

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Thermal comfort	- Include materials which can improve thermal insulation. - Use personal comfort systems (e.g., space heater/fans) to enhance the perceived thermal comfort. - Design spaces with separate thermal zones to accommodate varying user preferences. - Integrate shading, natural ventilation, and thermal mass to enable efficient regulation of indoor thermal conditions.	No match between LEED guidelines and the CREMA tool!
Visual comfort	- Install adjustable blinds, smart glass, or shading systems to reduce glare without blocking natural light. - Include mat, non-reflecting, and pastel tones for the walls. - Provide the windows with active systems for avoiding direct sunlight. - Promote natural light for the environment.	No match between LEED guidelines and the CREMA tool!

Table 2. Recommendations to integrate health and resilience criteria into LEED guidelines based on KPIs

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4.3. FINAL GUIDELINES FOR DEMONSTRATION SITE

Table 3, as part of the results for Subtask T8.5.3, provides a summary of the LEED v4.1 operations and maintenance [8] design practices assessed for their relevance to the Carmelitane building in Camerino, Italy. Each LEED design practice was first categorized into KPIs groups, and then rated according to its relevance related to four distinct categories using a color-coded system with the following meanings:

- **Relevant**: Relevant for the Italian pilot and a few measures are present in place (green).
- **Relevant but no data is available**: Relevant for the Italian pilot and a few measures are in place, but no data is available to evaluate their effectiveness (yellow).
- **Relevant but not applicable**: This would be good to include in the future as an improvement to the Italian pilot; relevant to the site but no measures are in place (orange).
- **Not relevant**: Not relevant for the Italian pilot (red).

The results revealed that many existing LEED design practices are relevant or potentially relevant for the Italian demonstration site, even if not yet fully implemented.

In terms of Building KPIs, for **Architectural resilience**, the Heat Island Reduction strategy is classified as relevant. The demonstration site benefits from a large green area, which supports non-roof measures to reduce heat effects. However, specific implementations such as high-reflectance roof materials or vegetated roofs are not present. For **Envelope resilience**, the Purchasing Policy is labeled relevant but not applicable. Additionally, Waste Performance is relevant, but no data is available. Regarding **Energy use and carbon emissions**, Energy Efficiency is relevant but not applicable, lacking an energy audit or facilities plan, while Energy Performance is relevant, but no data is available, with energy meters installed but no procedure established to collect the necessary data. For **Blue and green infrastructures**, Rainwater Management and Water Performance are both relevant but not applicable, as no procedures are currently implemented despite their potential benefit. In the **Maintenance** category, Grid Harmonization and Facility Maintenance and Renovation are both relevant but not applicable, indicating their importance for future implementation.

In terms of Human Health and Well-being KPIs related to **Behavioral adaptation**, Operable Windows are relevant, with the possibility to measure window areas against LEED minimum requirements. For **Satisfaction** aspects, Indoor Environmental Quality Performance is relevant but not applicable, suggesting that regular occupant satisfaction surveys could enhance future guidelines development. For **Privacy and safety**, the Integrated Pest Management Plan is relevant, but no data is available. In terms of **Perceived air quality**, Minimum Indoor Air Quality is relevant, but no data is available, lacking specific evaluative data, while Tobacco Smoke Control is relevant, with indoor smoking prohibited but no measures for outdoor spaces. Regarding **Acoustics comfort**, Building Materials (equipment design) are relevant and critical for the building's academic and spin-off activities. Finally, for **Visual comfort** Light Pollution Reduction is listed as relevant, noting that exterior fixtures exist but without specific reduction measures.

Importantly, partners' input, including feedback from UNICAM, CAM, and preliminary occupant surveys, has helped validate these results. This participatory approach ensures that the selected guidelines not only address technical performance but also reflect user needs and local priorities.

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KPIS	LEED DESIGN PRACTICES [8]	RELEVANCE	COMMENTS
Architectural resilience	***Heat Island Reduction (Building Roof):** Have in place strategies to minimize the project's overall contribution to heat island effects and that meet the following criterion: Area of Nonroof Measures (0.50) + Area of High-Reflectance Roof (0.75) + Area of Vegetated Roof (0.50) ≥ Total Site Paving Area + Total Roof Area. ***Nonroof Measures** aim to reduce heat and enhance shading by utilizing plants, vegetated planters, and structures with energy systems like solar panels or wind turbines. They also include the use of high solar reflectance materials, vegetated structures, and open-grid pavement systems with at least 50% unbound area. ***Vegetated Roof:** A vegetated roof must achieve full vegetative cover within three years of installation and be maintained annually to ensure plant health, structural integrity, and cleanliness of high-reflectance surfaces.	Relevant	Demonstration case includes a large green area but there is no High-reflectance Roof material and vegetated roof [9].
Structural resilience	Not available in LEED	Relevant	the Italian pilot frequently experiences intense summer heatwaves, and the building is located in a seismic zone.
Envelope resilience	***Purchasing Policy:** The intent is to reduce environmental harm from materials used in building operations by implementing an environmentally preferable purchasing (EPP) policy covering consumables, electronic equipment, and performance targets. **1)** Ongoing Consumables: For at least one month, track all ongoing consumable purchases. Purchase at least 50% or 75% (by cost, of total ongoing consumables that meet at least one of the following criteria. Recycled materials and products, extended use, bio-based products, etc. **2)** Building Materials: For at least one month, track all building material purchases (including furniture) used and/or installed as part of space reconfigurations, additions/alternations, or renovations. Purchase at least 50% or 75%, by cost, of total building materials that meet at least one of the following criteria under Reporting (Health Product Declaration, Cradle to Cradle Certification, etc.), Optimization (GreenScreen v1.2 Benchmark, EPD Optimization, etc.) and other attributes.	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	Being a public building owned and managed by the University of Camerino; there is a Purchasing Policy. Needs to be checked if this policy takes into account environmentally preferable purchasing (EPP).

	*Waste Performance: Track and measure all ongoing waste and durable goods waste. Measure the total weight of waste (in lbs., kg, or tons) that is generated, and the total weight that is diverted from landfills and incineration facilities for one full year or from a waste analysis. Exclude any facility renovations waste. Input generated and diverted waste totals and calculating a Waste Performance Score for the project.	Relevant but no data is available	There are storage locations in place for recyclable materials, including paper, glass, plastics, and metals and safely store and dispose of batteries and all lamps according to the local waste management policy, but there is no program to track and measure all ongoing waste and durable goods waste.
System resilience	Not available in LEED	Relevant	the Italian pilot frequently experiences intense summer heatwaves, and the building is located in a seismic zone.
Energy use and carbon emissions	***Energy Efficiency:** Conduct an energy audit meeting ASHRAE or EN 16247-2:2014 standards and maintain a facilities plan detailing building operations, occupancy schedules, HVAC and lighting setpoints, seasonal adjustments, system descriptions, and preventive maintenance requirements.	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	No audit and facilities plan are now available for the site.
	*Energy Performance: Install energy meters or sub-meters to measure total energy use monthly for a year, obtain an energy performance score, and earn LEED points based on greenhouse gas emissions and source energy, with interiors projects allowed to pro-rate energy use if applicable.	Relevant but no data is available	In the building, there are energy meters or sub-meters to measure total energy that could be useful to obtain an energy performance score and earn LEED points based on greenhouse gas emissions and source energy. However, it needs a procedure to collect the required energy data.
Blue and green infrastructures	*Rainwater Management: 1) Use low-impact development (LID) practices to infiltrate, evapotranspirate, collect and reuse water onsite from 25% of the impervious surfaces for the 95th percentile storm event. 2) Establish and implement an annual inspection and maintenance program of all rainwater management facilities to assure continued performance. 3) Document the annual inspections, including identification of areas of erosion, maintenance needs, and repairs. Perform necessary maintenance, repairs, or stabilization within 60 days of inspection.	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	No particular procedure for rainwater management is present in place

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	***Water Performance:** Projects must measure, and report total potable water use over a year, achieve a minimum water performance score of 40, and Interiors projects may pro-rate or provide base building data if fixtures are not included.	Relevant but no data is available	There are permanently installed water meters that measure the total potable water use, but it needs to have a procedure to collect potable water use.
	***Plants:** Plants that provide shade over paving areas (including playgrounds) on the site. For newly installed plants, base shade area on 10-year canopy width at noon. Shade with vegetated structures.	Relevant	Demonstration case includes a large green area.
Passive autonomy	Not available in LEED	Relevant	This should be considered due to its relevance for enhancing resilience and reducing reliance on active systems, especially in regions prone to energy disruptions or extreme weather events.
Risk avoidance	Not available in LEED	Relevant	the Italian pilot frequently experiences intense summer heatwaves, and the building is located in a seismic zone.
Maintenance	***Grid Harmonization:** The intent is to encourage participation in demand response programs to enhance energy system efficiency, reduce costs, improve grid reliability, and lower greenhouse gas emissions. Projects must assess building systems for demand response participation, excluding on-site electricity generation. Participate and include the DR processes in the current facilities requirements and operations and maintenance plan. Analyze the building's annual load shape and peak load based on metered electricity use and electric utility bills.	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	-
	***Facility Maintenance and Renovation:** Have in place a facility maintenance and renovation policy that includes guidelines for renovation and maintenance activities, using LEED rating system strategies, to be implemented at the discretion of building owners, operators, or tenants. Renovation activities include building improvements and tenant fit outs. Maintenance activities include general repair and replacement.	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	-
Physiological adaptation	Not available in LEED	Relevant	It is important in protecting occupant health during extreme heat events, and reducing heat-related health risks,

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			especially in the context of frequent summer heatwaves in the context.
Psychological adaptation	Not available in LEED	Relevant	It should be considered due to its role in supporting mental health and well-being during environmental stress, such as heatwaves or seismic events, by fostering a sense of safety, control, and comfort.
Behavioral adaptation	***Operable windows:** For naturally ventilated spaces, meet the minimum requirements for having operable openings.	Relevant	It is possible to measure the area of operable windows and check if it meets the minimum requirements.
Social adaptation	Not available in LEED	Relevant	It contributes to human resilience, enabling communities to respond collectively to natural hazards like earthquakes and heatwaves through strengthened social ties and mutual support.
Satisfaction	***Indoor Environmental Quality Performance:** For the occupant satisfaction survey, regular building occupants must be surveyed to assess how well the building is performing for the occupants, in particular with regard to indoor air quality and comfort.	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	It could be beneficial to adopt a regular building occupancy survey.
Privacy & safety	***Integrated Pest Management Plan:** It must be in place, including roles for the IPM team, pest monitoring, nonchemical preventive measures, and communication strategies, along with documentation and pesticide use notifications. Alternatively, a certified IPM service in good standing with recognized certifications such as GreenPro, EcoWise, or GreenShield can be used.	Relevant but no data is available	Needs to be checked if there are same pest management plan.
Perceived air quality	***Min. Indoor Air Quality:** To contribute to the comfort and well-being of building occupants by establishing minimum standards for indoor air quality (IAQ). Products (thermal and acoustic insulation, flooring materials and finishes, ceiling materials and finishes and wall materials and finishes) must either be inherently non-emitting or be tested. Ventilation system equipment and components must be maintained according to ASHRAE 62.1-2016 and included in the	Relevant but no data is available	-

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	operations and maintenance plan. For spaces with mechanical exhaust, the systems must be tested and confirmed to operate correctly as per the plan. Mechanically ventilated spaces must have outdoor air delivery measured to ensure they are within 10 percent of the required rates, with acceptable measurements taken within five years prior to project submission (see > LEED v4.1 O.M.).		
	***Tobacco Smoke Control:** Prohibiting smoking in the building. For this prerequisite smoking includes tobacco smoke, as well as smoke produced from the combustion of cannabis and controlled substances and the emissions produced by electronic smoking devices.	Relevant	It is prohibited smoking inside the building, but no prohibition measures are adopted for outdoor spaces.
	***Indoor Environmental Quality Performance:** Conduct an occupant satisfaction survey or indoor air quality evaluation, with a required number of survey responses specified. The air quality evaluation must test for inorganic contaminants, volatile organic compounds, and CO_2, with points awarded based on CO_2 and TVOC measurements (see the details> LEED v4.1 O.M.).	Relevant but not applicable. This would be good to include in the future as an improvement to the Italian pilot	-
Acoustics comfort	***Building Materials:** The equipment must have an ergonomic design to minimize vibration, noise, and user fatigue.	Relevant	This aspect is very important since the building hosts spin-off linked to scientific and academic activities. It should be checking all the equipment.
Thermal comfort	Not available in LEED	Relevant	This can support occupant health and well-being, as well as enhancing building resilience during extreme temperature events, such as the frequent summer heatwaves in the Italian context.
Visual comfort	***Light Pollution Reduction:** Option 1. Fixture Shielding: Shield exterior fixtures over 2,500 lumens to prevent light emission above 90 degrees. Option 2. Perimeter Measurements: Measure night illumination at least eight points along project boundary, ensuring lights-on levels are no more than 20% higher than lights-off levels.	Relevant	The building is located in the historical center of Camerino, there are exterior fixtures, but no particular measures are adopted for the reduction of light pollution.

Table 2. Applicability of LEED guidelines into Italian demonstration site

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4.4. STUDY DESIGN IMPLEMENTATION ON LIS PLATFORM

4.4.1. SUBJECTIVE AND OBJECTIVE MEASURES

In Subtask T8.5.4, the test protocol on multidomain comfort assessment was successfully implemented within the LIS platform, supporting practical data collection and integration from both physiological and environmental sensors as well as subjective comfort surveys.

A pilot test conducted at the LIS office involved 15 healthy volunteers (mean age 31.4 ± 7.8 years). The purpose was to validate the LIS platform's capability to integrate physiological sensors, environmental monitoring, and subjective comfort surveys in real-time [10]. Environmental parameters, including air temperature, relative humidity, CO_2 levels, PM1, PM2.5, PM10, VOCs, atmospheric pressure and illuminance, were consistently recorded, along with physiological signals such as PPG, EDA, skin temperature, and movement-related data. Figures 8 and 9 illustrate the LIS platform interface showing its real-time data visualization and sensor integration capabilities. Moreover, subjective comfort surveys were gathered through questionnaires administered at regular intervals, capturing visual, acoustic, thermal, and air-quality perceptions on a 5-point Likert scale. The results of the pilot test are presented in D10.2.

The pilot study validated the methodology's feasibility for its applications on WP11 test planned in the twin rooms of the Carmelitane building in Camerino, Italy. The results of this pilot study indicated the potential of the study design to collect and enhance occupant satisfaction and well-being, particularly under extreme conditions such as heatwaves. They also confirmed the platform's ability to collect environmental and physiological data and to handle multi-resident scenarios, with up to four participants being monitored simultaneously.

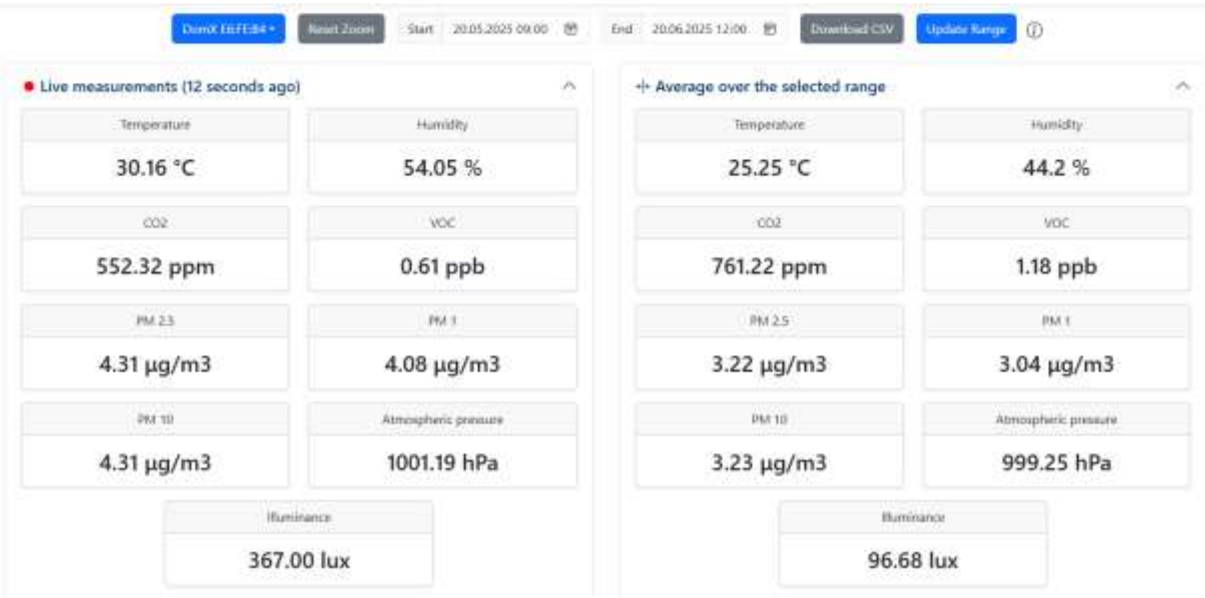

Figure 8. Real-time data and average environmental measures collected on the LIS platform

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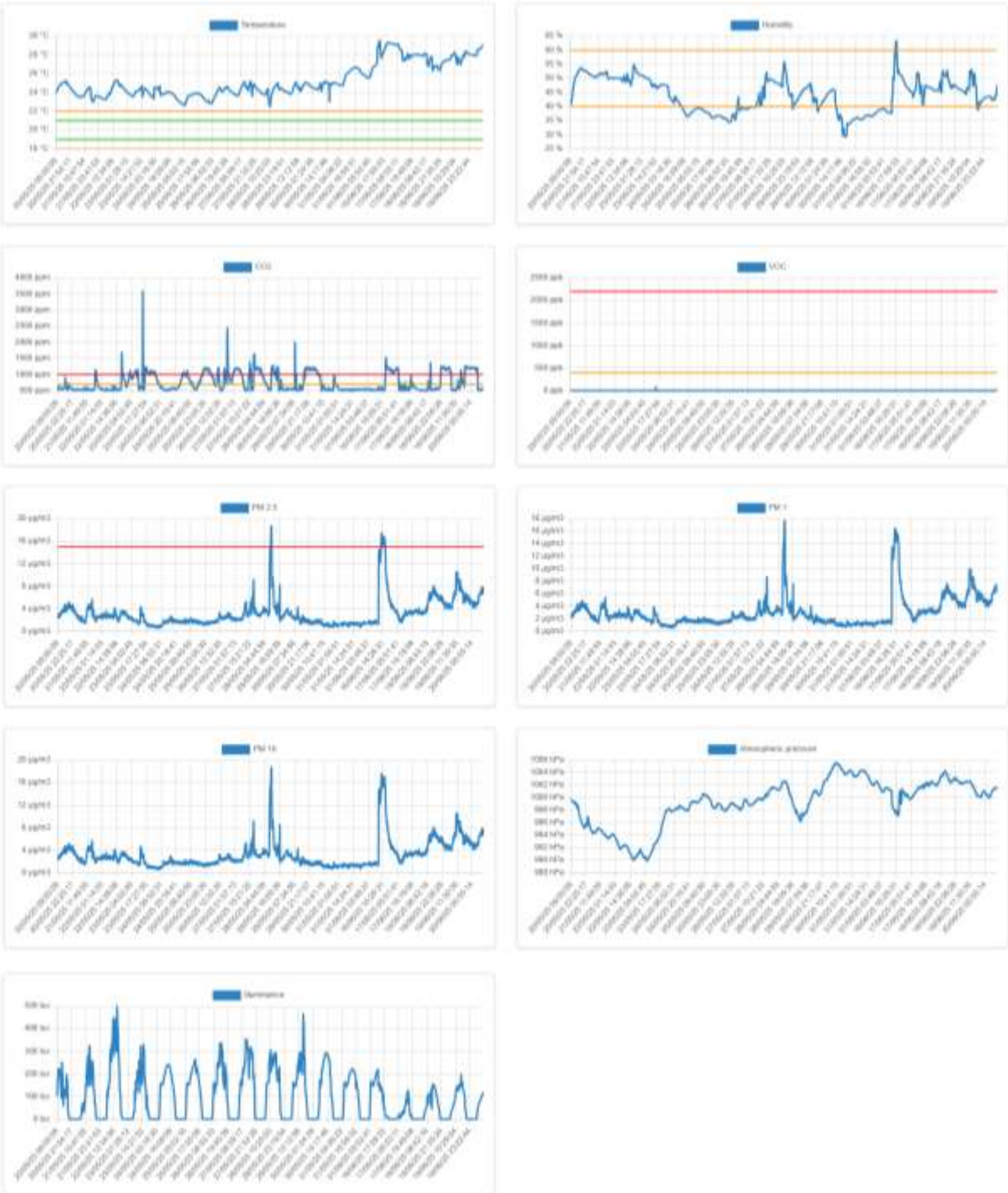

Figure 9. Visualization of environmental measures on the LIS platform

4.5. ETHICAL AND GDPR COMPLIANCE MEASURES

In Subtask T8.5.5, the ethical approval process for the study was initiated through the University of Camerino Research Ethics Committee, established by Rectoral Decree No. 425/2024. The submitted documentation, including the detailed test protocol, informed consent form, surveying methodology, and Principal Investigator's CV, was prepared and revised in accordance with the Committee's regulations.

The Ethics Committee is scheduled to meet on 29 September 2025 to issue its final opinion. At the time of this submission, the approval process remains ongoing, and the documentation package is under review. In parallel, to ensure participant privacy, data management procedures have been designed in compliance with GDPR guidelines, incorporating anonymization and secure data handling. This approach ensures that the experimental procedures safeguard participants' privacy and well-being throughout data collection.

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4.6. BEST-PRACTICE EXAMPLE

Subtask T8.5.6, as the final activity of Task T8.5, delivers a set of best-practice examples that significantly enhance the LEED guidelines by integrating quantitative, context-specific criteria tailored to the Italian demonstration site. The aim was to identify additional key criteria that are either currently missing from the KPIs or particularly relevant to the Italian demonstration site and integrate them into the LEED guidelines. The effectiveness of these criteria was also demonstrated through stakeholder-driven relevance assessments and measurable performance thresholds. Importantly, while previous steps were more general, this final activity focused on adding quantitative and measurable recommendations to enhance the LEED guidelines.

Five areas were identified as missing while highly relevant to the demonstration site, including:

- **Risk Assessment**
- **Management Under Climate Change**
- **Earthquake and Heatwave preparedness**
- **Mental and Physical Well-Being**
- **Cultural Heritage Aspects**

Partners were asked to provide key criteria across these five domains based on their expertise. Then, these key criteria were assessed for their relevance to the local context using a drop-down menu with a color-coded system with options:

- Relevant: Important and currently applicable in the context (green).
- Relevant but no data is available: Applicable, but implementation is limited by data (yellow).
- Relevant but not applicable: Not currently applicable, but useful for future improvements (orange).
- Not relevant: Not applicable to the context (red).

Comments from demo leaders provided additional context, particularly for data gaps or future applicability and the focus was on considering both the current state of the Carmelitane building and broader future implementation potential.

Table 4 shows the key criteria for the **Risk Assessment** area and their relevance to the local context of the demonstration site. 12 key criteria were identified while most criteria, such as Population exposed to climate risk (C01), Socio-demographic vulnerability index (C02), Frequency of extreme weather events (C03), Percentage of impervious surface in risk-prone areas (C04), Access to climate shelters (C05), Presence of critical infrastructure in risk zones (C06), Number of future climate scenarios considered (C07), Redundancy of critical infrastructure (C08), and Green space per capita (C09) were marked "Relevant," reflecting Camerino's exposure to heatwaves and seismic risks. The Carmelitane building's massive masonry walls provide comfort during heatwaves, and its location in a seismically damaged historic center underscores its social significance.

Criteria like Existence of updated emergency plans (C10), Budget allocated to climate adaptation (C11), and Technical capacity of public personnel (C12) were "Relevant but no data is available," indicating gaps in monitoring and planning.

Finally, risk assessment is considered vital for enhancing the building's resilience and supporting its community and the high relevance of risk-related criteria emphasizes the need for a robust risk assessment framework, tailored to local context and hazards. Moreover, data limitations suggest future investment and planning for monitoring systems.

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RISK ASSESSMENT						
KEY CRITERIA	DESCRIPTION	UNIT	THRESHOLD/ LIMIT	REFERENCE	RELEVANCE TO LOCAL CONTEXT	COMMENTS (UNICAM & CAM)
C01: Population exposed to climate risk	Percentage of the population living in areas exposed to one or more climate-related hazards (flooding, heat, drought, etc.)	%	<10% = Low exposure 10-30% = Medium >30% = High	IPCC AR6 (2022) [11]; EEA (2020) [12]; European Commission (2013) [13]	Relevant	The Italian territory is often subject to intense heatwaves during the summer season. With specific reference to the Carmelitane building, the structure is characterized by a massive masonry wall that ensures good internal comfort.
C02: Socio-demographic vulnerability index	Composite index evaluating factors such as age, income, access to services, health, and education.	Index (0-1)	<0.33 = Low 0.33-0.66 = Medium >0.66 = High	Cutter et el. (2003) [14]; EEA (2018) [15]; ESPON Climate (2011) [16]	Relevant	The Carmelitane building is located in the historic center of the municipality of Camerino, which was seriously damaged by the Central Italy earthquake sequence between 2016 and 2017. Most of the historic center remains inaccessible; however, the Carmelitane building did not suffer any damage and is currently usable. The building is part of the real estate assets of the University of Camerino and houses laboratories and business incubators. Therefore, even though the building is structurally safe, it is not socially neutral. Applying a socio-demographic vulnerability index allows for a better understanding of who uses it, what their needs are, how to support these individuals and the potential role of the building in a fragile and damaged urban context.
C03: Frequency of extreme weather events	Number of extreme events recorded during a given period (e.g., heatwaves, heavy rainfall)	Events/year	<1/year = Low 2-4 =Medium >4 = High frequency	Copernicus Climate Data Store [17]; IPCC (2021) [18]; EEA (2018) [15]	Relevant	Although the area of Camerino where the Carmelitane building is located has not yet been affected by extreme weather events, this type of assessment can be valuable in terms of prevention and user preparedness for such events.
C04: Percentage of impervious surface in risk-prone areas	Percentage of urban sealed surfaces (asphalt, concrete) in flood-prone zones	%	<30% =Low risk 30-60% = Medium >60% = High	EEA (2022) [19]; EEA (2020) [12]	Relevant	The area is not particularly exposed to flood risk; moreover, the Carmelitane building is surrounded by green areas with a low percentage of impervious surface coverage.
C05: Access to climate shelters	Percentage of the population within walking distance (<10	%	>80% = High access 50-80% =	WHO (2016) [20]; UNEP (2019) [21]	Relevant	The Carmelitane building is surrounded by green areas with tall vegetation; moreover, its massive

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	min) of cool, green, or shaded areas during heatwaves		Medium <50% = Low			structure made of thick stone masonry makes it particularly comfortable during heatwaves.
C06: Presence of critical infrastructure in risk zones	Number of hospitals, schools, or other key facilities located in high-risk areas	N°/by type	0= Ideal 1-3= Moderate concern >3 = Critical concern	UNDRR (2022) [22]; European Commission (2021) [23]	Relevant	The area is prone to seismic risk.
C07: Number of future climate scenarios considered	Number of climate scenarios (e.g., RCPs, SSPs) included in the prospective risk analysis.	N°	>3 (e.g., RCP 4.5, RCP8.5, SSP1) = Comprehensive 1-2 = Limited	IPCC (2021) [18]; Copernicus CDS [17]	Relevant	N/A
C08: Redundancy of critical infrastructure	Existence of alternate facilities or systems for key urban services	N° or presence/a bsence	Redundant = Resilient Non-redundant = Fragile	UNDRR (2022) [22]; ISO 37123 [24]	Relevant	N/A
C09: Green space per capita	Area of accessible urban green space per inhabitant	m^2/person	>9m2 = Adequate <9m2 = Insufficient	WHO (2016) [20]; EEA (2020) [12]	Relevant	N/A
C10: Existence of updated emergency plans	Presence and status of climate-related contingency/emergency plans	Binary (Y/N)	Updated <3 years = Adequate No plan = Deficient	UNDRR (2022) [22]	Relevant but no data is available	The civil protection plan is currently being updated.
C11: Budget allocated to climate adaptation	% of municipal budget for adaptation	%	>5% = Strong 1-5% = Moderate <1% = Weak	European Commission (2021) [23]; CEMR (2020) [25]	Relevant but no data is available	N/A
C12: Technical capacity of public personnel	N° of trained officials in climate resilience	N°/%	>50% trained = High capacity	IPCC (2022) [11]; ISO 14090 [26]	Relevant but no data is available	N/A

Table 3. Key criteria for risk asssessment domain and their relevance to the local context

Table 5 highlights the 10 key criteria identified for **Management Under Climate Change** domain and their relevance to the context of demonstration case. Criteria like Maintenance strategies (C03) and Maximum indoor temperature (C05) were assessed as "Relevant," with the public Carmelitane building adhering to maintenance protocols. However, criteria like Budget for healthcare (C01), Air quality (C02), Thermal comfort (C09) and Early warning systems (C10) were "Relevant but no data is available," while Self-cleaning coatings (C04), Renewable energy sources (C06), Sustainable construction materials (C07) and Water efficiency (C08) were "Relevant but not applicable" due to lack of implementation.

Furthermore, Thermal comfort (C09) and Maximum indoor temperature (C05) were "Relevant," highlighting occupant comfort needs in a warming climate. The absence of temperature and air quality sensors limits the ability to monitor healthy indoor conditions, especially during heatwaves when ventilation is critical. Installing detectors and smart thermostats could align the building with modern health standards and improve occupants' comfort levels. Also, future retrofits could integrate solar panels or other systems, using the building's public status for funding.

Overall, management strategies are partially in place, but gaps in data and advanced technologies (e.g., renewables monitoring) suggest opportunities to expand the refined LEED with climate adaptation measures.

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MANAGEMENT UNDER CLIMATE CHANGE						
KEY CRITERIA	DESCRIPTION	UNIT	THRESHOLD/ LIMIT	REFERENCE	RELEVANCE TO LOCAL CONTEXT	COMMENTS (UNICAM & CAM)
C01: Budget for healthcare	Adequate budget ensuring enhanced resilience to the health impacts of climate change. Overall health costs attributed to climate change due to EU's health systems emissions is around 25553.3 million €.	million €	lower limit = 18252.4 upper limit = 40155.2	Chen-Xu et al., (2024) [27]	Relevant but no data is available	N/A
C02: Air quality	Optimal CO_2 concentration is 400 ppm (0.04%).	ppm (%)	400 - 1000 (0.04 - 0.1)	CO_2 Meter [28]	Relevant but no data is available	Currently, there are no indoor CO_2 detectors installed.
C03: Maintenance strategies	Periodic inspections to notify users about possible issues/damages should be performed every 10 years for residential buildings and every 5 years for non-residential buildings (e.g. commercial, industrial and institutional buildings) Predictive maintenance strategies for the equipment; early warning systems	year	5-10	PSI (2025) [29]	Relevant	Since the Carmelitane building is a public building, it is provided with a maintenance strategy.
C04: Self-cleaning coatings	Hydrophobic and photocatalytic materials can reduce dirt accumulation. Water contact angle (WCA) is usually the quantitative criterion for water-wetting ability. When a solid surface is tilted to the minimum angle at which water droplets roll down the surface, this minimum angle is the sliding angle (SA).	°C	WCA > 150 °C SA < 10 °C (for super-hydrophobic materials)	Wu et al., (2023) [30]	Relevant but not applicable	N/A

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C05: Maximum indoor temperature	Indoor temperature reachable without an active system lower than 26°C	°C	26	Tham et al., (2022) [31]	Relevant	N/A
C06: Renewable energy sources	The National Energy and Climate Plan (PNIEC) sets a target of 39.4% renewable energy in final consumption by 2030. Additionally, Italy aims for 65% renewable electricity generation by 2030, up from a previous target of 55%.	%	>39.4 (gross final energy consumption) >65 % (electricity consumption)	PNIEC (2023) [32]	Relevant but not applicable	Currently, there are no systems for the use of energy from renewable sources.
C07: Sustainable construction materials	European Member States were obliged to prepare for reuse, recycle, and recover 70% of non-hazardous construction and demolition waste (CDW) by 2020, and minimize waste generation.	% of CDW recycling	>70	UNI Ente Italiano di Normazione [33]; EUR-Lex [34]; European Commission [35]	Relevant but not applicable	No works are planned for the building that could produce construction and/or demolition waste.
C08: Water efficiency	Water efficiency is the practice of reducing water consumption made by measuring the amount of water required for a particular purpose and is proportionate to the amount of essential water used. In Europe the average water consumption by household activities is 144 liters/person/day.	liters/per son/day	144	European Environment Agency [36]	Relevant but not applicable	It is possible to retrieve general data related to water consumption; however, it is very difficult, if not impossible, to distinguish the quantities based on specific uses.
C09: Thermal comfort	Percentage of hours that in one year fall in the defined comfort zones (>80%).	%	>80	ASHRAE 55 [37]	Relevant but no data is available	It might be difficult to retrieve hourly indoor temperature data for the past year.
C10: Early warning systems	Proportion of the population is covered by operational early warning systems for extreme weather events (e.g., floods, heatwaves).	%	>90% = Comprehensive 60-90% = Partial <60% = Limited	WMO (2022) [38]	Relevant but no data is available	At the present time, we have no information regarding this aspect.

Table 4. Key criteria for management under climate change domain and their relevance to the local context

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In terms of **Earthquake and Heatwaves** criteria, 10 key criteria were identified and assessed for their applicability to the local context (see Table 6).

Criteria like Solar reflectance index (SRI) - external pavement (C01), SRI - roof (C02), Thermal transmittance (U) (C06), and Building resistance to seismic action (C07) were "Relevant but no data is available," reflecting the lack of recent retrofitting or measurements. The building was renovated in 1993, so it doesn't meet today's standards, and retrofitting with high-SRI surfaces could reduce local heat island effects and enhance energy efficiency and heatwave resilience.

Green surface (C03), Solar transmission factor (C04), and PMV and PPD (C05) were "Relevant," indicating potential strengths in heatwave mitigation and seismic design features like Building footprint (C08).

In conclusion, seismic and heatwave resilience are crucial for Camerino, necessitating LEED enhancements with specific retrofitting and measurement criteria while data gaps highlight the need for updated materials and assessments.

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EARTHQUAKE AND HEATWAVES						
KEY CRITERIA	DESCRIPTION	UNIT	THRES HOLD/ LIMIT	REFERENCE	RELEVANCE TO LOCAL CONTEXT	COMMENTS (UNICAM & CAM)
C01: Solar Reflectance Index (SRI) - external pavement	To counteract the urban heat island effect and heatwaves, external pavements must have a solar reflectance index of at least 29.	-	29	Ministero della Transizione Ecologica (2022) [39]	Relevant but no data is available	This requirement is relevant for mitigating the urban heat island effect. However, the solar reflectance index (SRI) of the external pavements has not been measured, and the materials currently in place were not selected based on this criterion. Future renovations or surface treatments could take this parameter into account to enhance thermal comfort and environmental performance.
C02: Solar Reflectance Index - (SRI) roof	To counteract the urban heat island effect and heatwaves, for roofs with a slope greater than 15% the SRI must be at least 29, while for roofs with a slope equal to or less than 15% the SRI must be at least 76.	-	29 76	Ministero della Transizione Ecologica (2022) [39]	Relevant but no data is available	This requirement is relevant for reducing the urban heat island effect. However, the Solar Reflectance Index (SRI) of the roof materials has not been measured. The existing roofing was not selected based on SRI values, and its slope and surface properties may not meet the specified thresholds. Future refurbishments could consider high-SRI materials to improve thermal performance.
C03: Green surface	To counteract the urban heat island effect and heatwaves, the green surface must be at least 60% of the permeable land surface.	%	60	Ministero della Transizione Ecologica (2022) [39]	Relevant	N/A
C04: Solar transmission factor value (glass + solar screening)	To counteract heatwaves, the control of the direct solar radiation entering the indoor environment is ensured by providing solar shading with a total solar transmission factor coupled with the type of glass of the protected glazed surface ≤ 0.35 as defined by the UNI EN 14501 standard.	-	0.35	Ministero della Transizione Ecologica (2022) [39]	Relevant	N/A
C05: PMV and PPD	To ensure thermal comfort even during heatwaves, provide conditions conforming at least to class B according to the UNI EN ISO 7730 standard in terms of PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied)	-	class C	Ministero della Transizione Ecologica (2022) [39]	Relevant	N/A

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C06: Thermal transmittance (U)	Buildings in climate zone E (like Camerino) subject to energy requalification must have the following maximum thermal transmittances (U): 1. vertical opaque structures: U ≤ 0,28 (W/m2K) 2. opaque horizontal or inclined roofing structures: U ≤ 0,24 (W/m2K) 3. opaque horizontal floor structures, towards the outside subject to redevelopment: U ≤ 0,29 (W/m2K) 4. transparent and opaque technical closures and boxes, including frames: U ≤ 1,40 (W/m2K). NB: the values referred to "major renovation interventions of level 1 or 2" are different from those referred to energy requalification above.	W/m2 K	0,28 - 1,40	Ministero della Transizione Ecologica (2022) [39]	Relevant but no data is available	Although the building is located in climate zone E (Camerino), no energy requalification or major renovation interventions have been carried out to date. As a result, the existing building envelope has not been upgraded to meet the current thermal transmittance (U-value) limits established for energy requalification projects.
C07: Building resistance to seismic action (a_g)	Buildings must resist earthquakes with seismic action of: ≥ 0.35 (seismic zone 1); ≥ 0.25 (zone 2); ≥ 0.15 (zone 3); ≥ 0.05 (zone 4)	-	zone 1: 0,35 zone 2: 0,25 zone 3: 0,15 zone 4: 0,05	O.P.C.M. 3274 (2003) [40]	Relevant but no data is available	The building is located in a seismic zone, but the last renovation was carried out in 1993, prior to the introduction of current seismic design standards. No structural documentation is available to verify the building's resistance to seismic actions as defined by current regulations. Therefore, compliance with the specified seismic performance thresholds cannot be confirmed.
C08: Building footprint	To ensure the best response under seismic actions, the ratio between the two sides of a rectangle in which the building is inscribed must be less than 4.	-	4	O.P.C.M. 3274 (2003) [40]	Relevant	N/A
C09: Recesses and protrusions	To ensure the best response under seismic actions, any recesses or protrusions must not exceed 25% of the total size of the building in the direction of the recess or protrusion.	%	25	O.P.C.M. 3274 (2003) [40]	Relevant	N/A
C10: Continuous kerb	To ensure the best response under seismic actions, at each floor a continuous kerb must be created at the intersection between floors and walls with a width at least equal to that of the wall and a height equal to the height of the floor. A maximum setback of 6 cm from the external edge is permitted.	cm	6	O.P.C.M. 3274 (2003) [40]	Relevant	N/A

Table 5. Key criteria for earthquake and heatwaves domain and their relevance to the local context

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As shown in Table 7, 10 key criteria were identified for **Mental and Physical Well-being** domain. Strengths of the demonstration site include Water quality (C01), Operable windows (C05), Natural daylight access (C06), Access to nature (C07), Movement (C08), and Inclusive design (C09) all "Relevant," reflecting the building's design advantages (e.g., potable water, natural ventilation, green views).

Air quality (C02) and Thermal comfort (C03) were "Relevant but not applicable" due to missing sensors and humidity control, while Lightning quality (C04) was "Relevant but no data is available." Reliance on natural ventilation limits humidity control, affecting comfort and using mechanical systems could stabilize conditions, while increasing the buildings' energy footprint. Natural light is also a strength, but unmeasured illuminance levels hinder optimization, and light sensors could refine this aspect.

Additionally, Ergonomics (C10) was "Relevant but not applicable" due to substandard furniture and future ergonomic upgrades could enhance user experience.

In overall, the building supports well-being through natural features, but the redefined framework based on LEED could be enhanced with criteria for air quality monitoring, humidity control, and ergonomic standards to address these gaps.

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MENTAL AND PHYSICAL WELL-BEING						
KEY CRITERIA	DESCRIPTION	UNIT	THRESHOLD/ LIMIT	REFERENCE	RELEVANCE TO LOCAL CONTEXT	COMMENTS (UNICAM & CAM)
C01: Water Quality	Water intended for human contact, including drinking, cooking, food preparation, dishwashing, handwashing, bathing, or showering, must meet the following minimum safety criteria, in accordance with WHO guidance: Turbidity must be ≤ 1.0 NTU (Nephelometric Turbidity Units) to ensure effective disinfection and acceptable water clarity.	NTU	≤ 1.0	WHO (2022) [41]	Relevant	The water supply is classified as potable and regularly monitored by the competent public authority. Although national regulations do not explicitly define a numerical threshold for turbidity (e.g., ≤ 1.0 NTU), the water quality complies with Italian legislative standards for human consumption. Therefore, it can be reasonably assumed that the requirement is met. In any case, the water undergoes routine testing to ensure compliance with safety and potability criteria.
C02: Air Quality	Indoor air must meet or exceed WHO guidelines for key pollutants to minimize health risks. For PM2.5, annual mean should not exceed 5 μg/m³; for NO_2, annual mean should not exceed 10 μg/m³. Peak season 8-hour mean ozone should not exceed 60 μg/m³.	μg/m³	PM2.5 ≤ 5 NO_2 ≤ 10 O_3 ≤ 60	WHO (2021) [42]	Relevant but not applicable	At the moment, there are no indoor air quality sensors installed in the building to monitor concentrations of PM2.5, NO_2, or O_3. Therefore, compliance with WHO guidelines thresholds for these pollutants cannot be directly verified through measurement. Future implementation of monitoring devices could help assess and ensure adherence to indoor air quality standards.
C03: Thermal Comfort	The mechanical system has the capability of maintaining relative humidity between 30% and 60% at all times by adding or removing moisture from the air.	% RH	30%-60%	WELL Building Standard (2023) [43]	Relevant but not applicable	The building is not equipped with a mechanical ventilation system capable of actively controlling indoor relative humidity within the 30–60% range by adding or removing moisture. As a result, humidity levels depend primarily on natural ventilation and ambient conditions and cannot be regulated mechanically.
C04: Light Quality	Ensure sufficient task lighting: horizontal illuminance at the work-plane (0.75 m above floor) should meet the minimum level for general office tasks by providing a minimum horizontal illuminance of 500 lux.	lux	≥ 500 lux	EN 12464-1 (2022) [44]	Relevant but no data is available	All rooms are equipped with both natural daylight and ceiling-mounted fluorescent (neon) artificial lighting. However, no measured data on actual horizontal illuminance (lux levels) at the work-plane are currently available. Therefore, while appropriate lighting is provided in general terms, compliance with the 500 lux requirement cannot be quantitatively confirmed.

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C05: Operable Windows	Project must meet one of the following: (1) At least 75% of regularly occupied spaces have operable windows that provide access to outdoor air; OR (2) On each floor, the area of openable windows is at least 4% of the indoor occupiable space area.	% of spaces % of area	≥75% of regularly occupied spaces with operable windows OR openable window area ≥4% of occupiable space per floor	WELL Building Standard (2023) [43]	Relevant	The building satisfies option (1): more than 75% of regularly occupied spaces in the building are equipped with operable windows that provide access to outdoor air. This ensures natural ventilation and user control over indoor air exchange.
C06: Natural Daylight Access	Ensure that at least 51% of the floor area across all regularly occupied spaces, including workspaces and common areas, has access to natural daylight through transparent windows. Skylights can be included as a daylit area.	% of floor areas	≥51%	Fitwel (2022) [45]	Relevant	The building meets the requirement: more than 51% of the floor area across all regularly occupied spaces—including workspaces and common areas—has access to natural daylight through transparent windows. This ensures adequate daylight penetration and visual comfort for occupants.
C07: Access to Nature	At least 75% of workstations, conference room seats, classroom seats, and seating within common spaces must either have a direct line of sight to indoor plant(s), water feature(s), or nature view(s), or be within 33 ft (10 m) of such features.	% of seats	≥75%	WELL Building Standard (2023) [43]	Relevant	At least 75% of rooms and offices in the Carmelitane building have windows with a direct view of the green space located in front of the building. This provides occupants with a consistent visual connection to nature, in accordance with the guidelines criteria.
C08: Movement	At least one of the following outdoor physical activity spaces must be within a 0.25 mile (400 m) walk distance of the project boundary and available at no cost to regular occupants: green space (e.g., park, walking/biking trail), blue space (e.g., swimming area), recreational field or court, fitness zone with all-weather equipment, or, for projects with child occupants, a playground.	Presence/yes-no	≥1 space within 400 m	WELL Building Standard (2023) [43]	Relevant	The building is located within a green recreational area and meets the requirement. Additionally, a pastoral center located within 400 meters of the project boundary includes a small community-accessible futsal field and a beach volleyball court, both available for outdoor physical activity at no cost to regular occupants.
C09: Inclusive Design	Built environments must ensure accessibility and usability for all users, including persons with disabilities, in accordance with ISO 21542:2021. Minimum requirements include step-free access routes (≤ 5% gradient),	mm %	Door width ≥ 850 mm Gradient ≤ 5% Turning space ≥ 1500 mm	ISO 21542 (2021) [46]	Relevant	N/A

	door widths ≥ 850 mm, and turning spaces ≥ 1500 mm in diameter.					
C10: Ergonomics	Office task chairs shall conform to BS EN 1335-1:2020 (Dimensions) and BS EN 1335-2:2018 (Safety & Strength) Type B classification to accommodate 95% of user anthropometrics. Minimum adjustability ranges ensure proper posture and circulation.	mm	Seat height: 420–520 mm (adjustment range ≥ 100 mm) Seat depth: 380–460 mm (adjustment range ≥ 80 mm) Backrest height: 400–475 mm (adjustment range ≥ 75 mm)	BS EN 1335-1 (2020) [47] BS EN 1335-2 (2018) [48]	Relevant but not applicable	The current office task chairs do not all meet the ergonomic standards specified by BS EN 1335-1:2020 and BS EN 1335-2:2018 Type B classification. While this requirement is not currently applicable, it is considered relevant and may inform future upgrades aimed at improving user comfort and posture.

Table 6. Key criteria for mental and physical well-being domain and their relevance to the local context

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Table 8 shows the key criteria for **Cultural Heritage Aspects** and their relevance to the local context. Most criteria such as Visitor density control (C01), Exhibit illuminance (C02), Relative humidity stability (C05) was "Not relevant," as the Carmelitane building is not a heritage site housing artifacts. However, Preventive maintenance interval (C06) and Emergency preparedness (C07) were "Relevant," emphasizing structural preservation needs. Given the building's seismic location, preparedness plans are essential and need to be considered in future plans.

Vibration exposure (C03) and Temperature measurement accuracy (C04) were "Relevant but not applicable," suggesting future relevance if monitoring is implemented. In terms of cultural heritage criteria, preservation and safety measures could enhance LEED for heritage public buildings in historic contexts, focusing on maintenance and monitoring.

In conclusion, the Best-Practice Example exemplified how global standards on resilience, sustainability and health and well-being can be adapted to address local challenges, climate risks, seismic vulnerability, and occupant needs.

The framework successfully incorporated additional KPIs for risk assessment, climate adaptation, seismic and heatwave preparedness, health and well-being, and cultural heritage considerations, addressing gaps in LEED and reflecting Camerino's unique context. Strengths included the building's natural ventilation, daylight access, and heatwave resilience, while data gaps (e.g., air quality, seismic retrofitting) and unimplemented measures (e.g., renewables, ergonomics) highlighted opportunities for future action.

The results delivered ready-to-implement, KPI-driven guidance for stakeholders involved in the planning, designing, and managing of built environments. These best practices provided a scalable model for other regions facing similar hazards, demonstrating how to balance health, resilience, and sustainability in building design and management.

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CULTURAL HERITAGE ASPECTS						
KEY CRITERIA	DESCRIPTION	UNIT	THRESHOLD/ LIMIT	REFERENCE	RELEVANCE TO LOCAL CONTEXT	COMMENTS (UNICAM & CAM)
C01: Visitor Density Control	Limit peak simultaneous visitors to ≤ 1 person per 10 m^2 of publicly accessible site area to prevent wear, overcrowding, and impact on fabric.	persons/m^2	≤ 0.10 persons/ m^2 (i.e., ≥ 10 m^2 per person)	Feilden, B. M. (1994) [49]	Not relevant	The building is the Camerino university property and not open to public visitors.
C02: Exhibit Illuminance	Limit illuminance on sensitive artifacts to ≤ 50 lux (max 100 lux for less-sensitive materials) and ensure ≤ 200 lux in non-display zones, measured at object surface.	lux	≤ 50 lux (sensitive) ≤ 100 lux (moderate) ≤ 200 lux (ambient)	CCHE [50]	Not relevant	The building is the Camerino university property and not intended to be used as an exhibition of artifacts.
C03: Vibration Exposure	Maintain RMS vibration velocity (weighted Wm) ≤ 0.1 mm/s in occupied heritage interiors to prevent structural fatigue and artifact damage.	mm/s (RMS)	≤ 0.1 mm/s	ISO 2631-2 (2003) [51]	Relevant but not applicable	This is a relevant requirement for heritage interiors, as excessive vibration could lead to structural fatigue or damage to historical elements. However, no vibration monitoring has been conducted to date in the building. While current activities are not expected to generate significant vibrations, future assessments may be considered to ensure preservation standards are met.
C04: Temperature Measurement Accuracy	Use calibrated instruments per EN 15758 to measure air and surface temperatures; ensure sensor accuracy ±0.3 °C and that ≥ 98 % of logged values fall within ±0.5 °C of true temperature to avoid material stress.	°C	Instrument accuracy ±0.3 °C, ≥ 98 % readings within ±0.5 °C	EN 15758 (2010) [52]	Relevant but not applicable	This requirement is relevant for ensuring the protection of materials in heritage buildings. However, calibrated instruments compliant with EN 15758 are not currently used to monitor air and surface temperatures in the building. While environmental conditions are generally stable and no material stress has been observed, future implementation of precise monitoring tools could support preventive conservation efforts.
C05: Relative Humidity Stability	Maintain relative humidity (RH) in heritage spaces within 45%-55% to prevent material degradation (e.g., wood warping, textile embrittlement). Fluctuations	% RH	45%-55%, ±5% daily fluctuation	EN 15757 (2014) [53]	Not relevant	N/A

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	must not exceed ±5% RH within a 24-hour period.					
C06: Preventive Maintenance Interval	Perform preventive maintenance on roofing, rainwater goods, and external drainage systems at intervals ≤ 12 months, per EN 16095 guidelines, to minimize water ingress and fabric decay.	months	Maintenance interval ≤ 12 months	EN 16095 (2011) [54]	Relevant	N/A
C07: Emergency Preparedness	Smoke detectors covering ≥ 90% of spaces and sprinklers in ≥ 80% of high-risk areas (where compatible) balance protection with material preservation.	%	Smoke detectors covering ≥ 90% sprinklers in ≥ 80% of high-risk areas	NFPA (909-2021) [55]	Relevant	N/A
C08: Cultural Representation	Ensure ≥ 75% of interpretive materials reflect local cultural narratives and community input, per UNESCO Operational Guidelines.	%	≥ 75%	The UNESCO Operational Guidelines [56]	Not relevant	N/A
C09: Air Quality Control	Maintain indoor air quality by limiting particulate matter (PM2.5) to prevent deposition on artifacts and surfaces, which can cause chemical degradation or soiling. Air filtration systems should target PM2.5 levels to ensure preservation of sensitive materials.	μg/m³	≤ 10 μg/m³ (annual average)	ICOM-CC (2014) [57]	Not relevant	N/A
C10: Air Quality for Artifact Preservation	Control sound levels to minimize disturbance to visitors and prevent vibrational damage to fragile artifacts or structures. Maximum sound pressure levels in exhibition spaces should be kept within acceptable limits to ensure a conducive environment for heritage appreciation.	db	≤ 50 dB(A) (average sound pressure level during operating hours)	ISO 12913-1 (2016) [58]	Not relevant	The building is the Camerino university property and not intended to be used as an exhibition of artifacts.

Table 7. Key criteria for cultural heritage aspects and their relevance to the local context

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5. OUTPUTS FOR OTHER WPS

The results of Task 8.5 will contribute directly to several other work packages within the MULTICLIMACT project, supporting the practical application and validation of human-centred design strategies.

More specifically, the outputs will support WP11, Task 11.1 (demonstration of the MULTICLIMACT framework at the building scale), where the actual implementation and monitoring activities at the Italian demonstration site in Camerino will take place. The adapted guidelines, and the study design developed in Task 8.5 will provide the main framework for assessing environmental conditions and their impact on people's physical, mental, and social well-being. These outcomes will be operationalized via the LIS platform, forming the basis for continuous data collection and evaluation and leading to a data-driven understanding of the effects of built environment on human health and well-being.

Additionally, the ethical and GDPR compliance measures established in this task will provide a robust framework for data protection and participant well-being, applicable to other tasks within the MULTICLIMACT project that involve humans. The best-practice example developed from this task will serve as a guideline for integrating health and resilience KPIs into built environment design, contributing to other work packages and offering valuable insights for future initiatives.

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6. CONCLUSION

The present document is intended to provide a framework for human-centred built environment design for improving peoples' health and well-being and its development for the application to the Italian demonstration case. It describes the methodology and outcomes of Task 8.5 of the MULTICLIMACT project. The task had a focus on developing building guidelines, health and well-being criteria and the best-practice example.

The process began with T8.5.1, where a desk review and partner workshops identified LEED v4.1 as the most suitable guidelines due to its ability to address the site-specific hazards of earthquakes and heatwaves while incorporating KPIs for building resilience and human health and well-being. In T8.5.2, all partners, and demonstration site leaders collaborated to integrate health and well-being evaluation criteria into LEED v4.1, addressing gaps in building resilience KPIs, and human-centric KPIs. Recommendations such as passive solar optimization, self-healing materials, and occupant satisfaction surveys were incorporated, tailoring the framework to support both structural integrity and occupant well-being.

The practical implementation of these activities was in T8.5.3, where the study design was executed on the LIS platform. A pilot test serving as co-creation measure validated the platform's capacity to integrate environmental measures, physiological data, and subjective comfort surveys, proving its feasibility for real-time assessment of occupant well-being at the Carmelitane building. Ethical and GDPR compliance was carried out on T8.5.4, with the University of Camerino Research Ethics Committee approving the study protocol. T8.5.5 focused on stakeholder engagement through co-creation, refining the framework to reflect local needs and priorities, which strengthened its applicability.

The final work of Task 8.5 was conducted within T8.5.6 and resulting in a best-practice example that redefined LEED v4.1 with context-specific key criteria tailored to the Italian demonstration site. These quantitative key criteria addressed critical aspects such as risk assessment, management under climate change, earthquake and heatwave preparedness, mental and physical well-being, and cultural heritage aspects, and important domains to Camerino's challenges. Strengths like natural ventilation and daylight access were highlighted, while gaps such as air quality monitoring and seismic retrofitting were identified for future improvement.

Moving forward, the outputs of Task 8.5 provide a solid foundation for the next phases of the MULTICLIMACT project. The refined guidelines not only improve the health and resilience of the Carmelitane building but also provide a scalable, KPI-driven best-practice example for other regions facing similar hazards. By balancing health, resilience, and cultural considerations, Task T8.5 demonstrates a replicable approach to designing built environments that prioritize human well-being in the face of multifaceted climate and natural challenges.

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ANNEX A

T2.5. PLANNING AND DESIGNING A HUMAN-CENTERED BUILT ENVIRONMENT FOR IMPROVING PEOPLE'S HEALTH AND WELL-BEING

	Additional information	General Features: Type						General Features: Primay Target						General Features: Final Output						General Features: Scale				Content information: Demo-sites aspects					Content information: Building Resilience									Content information: Human Resilience: Health				Content information: Human Resilience: Well-being						Consideration of potential indicators				Implementation Details		
Title	How relevant is it to climate change?	Guideline	Rating system	Certificates	Toolkit	Report	Other	Policy makers	Communities	Investors and developers	Architects and designers	Occupants and users	Environmental advocates	Principles	Guidelines /Tools	Design solutions	Reports	Policies	Others	Building	Urban	Territorial	Multiple	Earthquake	Flood	Drought	Heatwaves	Cultural heritage	Architectural resilience	Structural resilience	Envelope resilience	System resilience	Energy use and carbon emissions	Blue and green infrastructures	Passive autonomy	Risk Avoidance	Maintenance	Physiological adaptation	Psychological adaptation	Behavioral adaptation	Social adaptation	Satisfaction	Privacy & Safety	Perceived Air quality	Acoustic comfort	Thermal comfort	Visual comfort	Risk factors like age, health symptoms, ..	Decarbonization	Digital solutions	Construction techniques	Administrative	Implementation material	Assessment procedures
LEED Reference Guide for Building Design and Construction: LEED V4 Edition	Very relevant		•					•	•	•	•	•	•						•	•	•		•	1	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1		•	•
Promoting Health While Mitigating Climate Change	Very relevant						•	•									•			•		•		0	1	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0			•
Design for Well-being—Framework for Design Excellence	indirect				•				•		•	•		•	•					•		•	•	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1		•	•
WELL Health-Safety Rating	indirect		•					•		•	•				•				•	•				0	0	0	0	0	1	0	1	1	1	1	1	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0		•	
The Living Building Challenge (LIVING BUILDING CHALLENGE SM 4.0)		•								•	•					•				•				0	0	0	0	0	1	0	1	1	1	1	1	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0		•	
The Fitwel Certification System				•					•		•	•							•	•				0	1	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0			•

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T2.5. PLANNING AND DESIGNING A HUMAN-CENTERED BUILT ENVIRONMENT FOR IMPROVING PEOPLE'S HEALTH AND WELL-BEING

	Additional information	General Features																						Content information														Human Resilience										Consideration of potential indicators				Implementation Details		
		Type						Primay Target						Final Output						Scale				Demo-sites aspects					Building Resilience									Health				Well-being												
Title	How relevant is it to climate change?	Guideline	Rating system	Certificates	Toolkit	Report	Other	Policy makers	Communities	Investors and developers	Architects and designers	Occupants and users	Environmental advocates	Principles	Guidelines /Tools	Design solutions	Reports	Policies	Others	Building	Urban	Territorial	Multiple	Earthquake	Flood	Drought	Heatwaves	Cultural heritage	Architectural resilience	Structural resilience	Envelope resilience	System resilience	Energy use and carbon emissions	Blue and green infrastructures	Passive autonomy	Risk Avoidance	Maintenance	Physiological adaptation	Psychological adaptation	Behavioral adaptation	Social adaptation	Satisfaction	Privacy & Safety	Perceived Air quality	Acoustic comfort	Thermal comfort	Visual comfort	Risk factors (like age, health symptoms, ..	Decarbonization	Digital solutions	Construction techniques	Administrative	Implementation material	Assessment procedures
The Sustainable SITES Initiative (SITES)	Very relevant		•							•	•								•	•	•		•	0	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1	0	1	0	1	1	0	0	0	1	1	0	1		•	
The ULI Building Healthy Places Toolkit					•					•	•				•	•				•	•		•	0	0	0	1	0	1	0	1	1	0	1	1	0	0	0	0	1	1	0	1	1	1	0	1	0	1	0	1		•	
2020 Enterprise Green Communities Criteria & Certification The Standard for Sustainable Futures		•								•									•	•				0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	0	0	1	0	1	1	1	0	1	1	1	0	1			
Safe and Healthy School Environments							•	•				•			•					•				0	0	0	1	0	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1		•	
14 Patterns of Biophilic Design						•				•	•						•			•	•		•	0	1	1	0	0	1	0	1	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	1	0	0	0	1		•	
Active Design Guidelines, PROMOTING PHYSICAL ACTIVITY AND HEALTH IN DESIGN		•						•		•	•				•	•				•	•		•	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	0	0		•	

ANNEX B

Informed consent form

WELL-BEING ASSESSMENT IN THE BUILT ENVIRONMENT

Principal investigator

Dall'Asta Andrea

Morici Michele

University of Camerino

Camerino, Maggio 2025.

TITLE OF THE STUDY

Well-being assessment in the built environment.

PRINCIPAL INVESTIGATOR

Dall'Asta Andrea

Morici Michele

University of Camerino

Address: Piazza Cavour 19F, 62032 Camerino (MC)

City: Camerino Region: Marche

Email: andrea.dallasta@unicam.it

michele.morici@unicam.it

STUDY PROPOSAL

Assessment of subjects' well-being in the built environment based on physiological and environmental signals and surveys on multidomain comfort.

- **Duration**: July 2025-July 2026
- **Location**: Ex Carmelitane Building, via Viviano Venanzi 16, Camerino (MC)
- **Collected data**:
  - Demographic information
  - Physiological signals (e.g., photoplethysmographic signal, electrodermal activity signal, skin temperature, etc.)
  - Motion-related signals collected on the wrist (by means of accelerometer, gyroscope, and magnetometer)
  - Environmental signals (e.g., air temperature and relative humidity)
  - Subjective data on participants' perception of the environment and well-being
- **Acquisition devices**
  - Multidomain smartband (e.g., to measure heartbeat, skin temperature, etc.)
  - Environmental sensors (e.g., air temperature and relative humidity)

PROCEDURE

Eligibility criteria

The participants to the tests should be healthy and without a particular clinical history possibly impacting on the results. They are asked to not take medications for 24 hours before the study.

Data acquisition procedure

1. Collection of the subject's demographic data

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2. Preparation and positioning of sensors
3. The test starts with the start of the signals acquisition. During the tests, the subjects carry out normal office activities (e.g., writing at laptop, meetings, etc.), while being asked to answer some questionnaires at regular intervals. The room thermoregulation is not altered; normal operations of natural ventilation (e.g., windows opening) or personal comfort tools (e.g., space heater) are allowed.
4. Removal of sensors at the test end.

Data processing and analysis

The collected signals are processed both through the LIS platform tools and in MATLAB/Python environment for additional analyses (which in future will be integrated into the digital platform itself).

Features possibly related to environmental quantities as well as to personal comfort and perception will be extracted from the signals. Hence, synthetic indices describing the subject's well-being and general health will be proposed.

RISKS

There are no safety concerns in relation to the tests as participants will not be exposed to any conditions that are outside their normal working conditions.

PRIVACY

No identifying information will be inserted in the forms.

The principal investigators will do their best to preserve your privacy, including:

- Assignment of encoded names/numbers for the participants to be used in the whole study.
- No preservation of notes, interview transcriptions, and other identifying information related to the participant.

The participants' data will be kept confidential, except in cases where the researcher is legally required to report specific incidents.

REMUNERATION

The participation is voluntary and free.

CONTACT INFORMATION

If participants have issues related to the tests and/or would like to have further information, they can consider the contact information provided on the first page.

VOLUNTARY PARTICIPATION

The participation to the study is voluntary. The subject can choose to exit the study in any time. If she/he chooses to participate to the study, an informed consent form must be signed. After having signed the informed consent form, the participant can still exit the study at any time and without any justifications. In that case, all the data related to the participants will be destroyed; the choice will not influence at all any relationship with the researcher.

CONSENT

I have read and understood the information provided and I have had the possibility of asking questions. I understand that my participation is voluntary, and I am free to exit the study at any time, without motivations nor consequences. I voluntarily accept to take part in this study.

Participant's signature ______________________________
Date __________

Researcher's signature ______________________________
Date __________

SURVEY SUBJECT # ___

1. Name ____
2. Cognome: ____
3. Age: ____
4. Gender: ☐ Male ☐ Female ☐ Other
5. Job: ____
6. Weight: ____
7. Height: ____

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ANNEX C

Part I: General information

1	Age	_________
2	Gender	□ Male □ Female □ Nonbinary
3	Weight (kg)	_________
4	Height (cm)	_________
5	What is your highest general school qualification?	□ Without a qualification □ Graduation after a maximum of seven years of school attendance □ Intermediate school leaving certificate or equivalent qualification □ Entrance qualification for universities of applied sciences □ General or subject-specific higher education entrance qualification □ Bachelor's degree □ Master/Diploma □ Doctorate □ Vocational training
6	What is the gross annual salary of your household? Explanation: Please include regular payments such as pensions, housing benefit, child benefit, maintenance payments, etc. before deductions for taxes and social security contributions.	□ Low (<15 k€) □ Medium (15 k€ < x < 50 k€) □ High (> 50 k€)
7	Do you regularly practice sport activities?	□ Yes □ No
8	How would you describe your current state of health?	□ -2 Very bad □ -1 Rather bad □ 0 Satisfactory □ +1 Rather good □ +2 Very good
9	Do you have the following health conditions that make you more sensitive to temperature?	□ Cardiovascular diseases Yes/No □ Respiratory diseases Yes/No □ Heat intolerance medications Yes/No □ Other conditions: _________
10	Do you have the experience of staying regularly in the following extreme temperature conditions?	□ Exposed to heatwaves □ Living in desert climates □ Sauna □ Other: _________

The following questions focus on social support, which is one of several factors that may influence overall well-being.

Please indicate how you feel about each statement	Very Strongly Disagree	Strongly Disagree	Mildly Disagree	Neutral	Mildly Agree	Strongly Agree	Very Strongly Agree
There is a special person who is around when I am in need.							
There is a special person with whom I can share my joys and sorrows.							
My family really tries to help me.							
I get the emotional help and support I need from my family.							
I have a special person who is a real source of comfort to me.							
My friends really try to help me.							
I can count on my friends when things go wrong.							
I can talk about my problems with my family.							
I have friends with whom I can share my joys and sorrows.							
There is a special person in my life who cares about my feelings.							
My family is willing to help me make decisions.							
I can talk about my problems with my friends.							

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Part II: Multidomain comfort

5	According to this scale, how do you perceive the surrounding visual environment right now?	□ -2 highly discomfortable □ -1 slightly discomfortable □ 0 neutral □ +1 comfortable □ +2 highly comfortable
6	According to this scale, how do you judge your visual sensation with respect to the surrounding environment right now?	□ -2 very dark □ -1 slightly dark □ 0 neutral □ +1 slightly bright □ +2 very bright
7	According to this scale, how would you prefer the surrounding visual environment at the moment?	□ -2 very darker □ -1 slightly darker □ 0 neutral □ +1 slightly brighter □ +2 much brighter
8	According to this scale, how are you satisfied with the surrounding visual environment?	□ -2 very dissatisfied □ -1 slightly dissatisfied □ 0 neutral □ +1 slightly satisfied □ +2 very satisfied

9	According to this scale, how do you perceive the surrounding acoustic environment right now?	□ -2 highly discomfortable □ -1 slightly discomfortable □ 0 neutral □ +1 comfortable □ +2 highly comfortable
10	According to this scale, how do you judge your acoustic sensation with respect to the surrounding environment right now?	□ -2 very quiet □ -1 slightly quiet □ 0 neutral □ +1 slightly noisy □ +2 very noisy
11	According to this scale, how would you prefer the surrounding acoustic environment at the moment?	□ -2 very quieter □ -1 slightly quieter □ 0 neutral □ +1 slightly noisier □ +2 much noisier
12	According to this scale, how are you satisfied with the surrounding acoustic environment?	□ -2 very dissatisfied □ -1 slightly dissatisfied
		□ 0 neutral □ +1 slightly satisfied □ +2 very satisfied

13	According to this scale, how do you perceive the air quality of the surrounding environment right now?	□ -2 highly discomfortable □ -1 slightly discomfortable □ 0 neutral □ +1 comfortable □ +2 highly comfortable
14	According to this scale, how do you judge your air quality sensation with respect to the surrounding environment right now?	□ -2 very stuffy air □ -1 slightly stuffy air □ 0 neutral □ +1 quite fresh air □ +2 very fresh air
15	According to this scale, how would you prefer the air in the surrounding environment at the moment?	□ -2 much closer air □ -1 slightly closer air □ 0 neutral □ +1 slightly purer air □ +2 much purer air
16	According to this scale, how are you satisfied with the air quality of the surrounding thermal environment?	□ -2 very dissatisfied □ -1 slightly dissatisfied □ 0 neutral □ +1 slightly satisfied □ +2 very satisfied

17	Comprehensively, how do you feel in the surrounding environment? ____	
18	How do you rate your overall comfort level right now?	□ -2 Terrible □ -1 Poor □ 0 Neutral □ +1 Good □ +2 Excellent
19	Overall, how satisfied are you with the surrounding environment?	□ -2 very dissatisfied □ -1 slightly dissatisfied □ 0 neutral □ +1 slightly satisfied □ +2 very satisfied

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19	How satisfied are you with your work performance at the moment?	□ -2 very dissatisfied □ -1 slightly dissatisfied □ 0 neutral □ +1 slightly satisfied □ +2 very satisfied
20	Are you sweating right now?	□ Much sweating, droplet falling □ Sweating, skin droplet □ Slightly sweating, skin moist □ No sweating, dry skin
21	How would you rate your ability to perform normal daily activities (climbing the stairs, hiking, going shopping, etc.) right now?	□ -2 Very low □ -1 Low □ 0 Neutral □ +1 High □ +2 Very high
22	How would you rate your most prevailing activity level during the last 30 min?	□ Sitting □ Standing □ Walking □ other
23	Which clothing are you wearing right now? (Please select all items that apply)	□ underpants □ underwear with short sleeves and legs □ underwear with long sleeves and legs □ Trousers □ shorts □ Skirt □ Shirt □ T-shirt □ jacket □ heavy quilted outer jacket and overalls □ socks □ shoes □ cap □ gloves
24	Would you like to perform one/more of the following actions?	□ Open a window? □ Use a space heater?

Positive and Negative Affect Schedule (PANAS)

On a 5-point scale, please rate each of the following items during the test.

1	2	3	4	5
Not at all	*A little*	*Enough*	*A lot*	*A great deal*

	Item	Rate
Positive affect	Attentive	
	Active	
	Alert	
	Excited	
	Enthusiastic	
	Determined	
	Inspired	
	Proud	
	Interested	
	Strong	
Negative affect	Hostile	
	Irritable	
	Ashamed	
	Guilty	
	Distressed	
	Upset	
	Scared	
	Afraid	
	Jittery	
	Nervous	

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ANNEX D

UNIVERSITÀ DI CAMERINO

MODULO 1

Richiesta di Parere al Comitato Etico della Ricerca di Ateneo

- **Titolo del progetto:**

MULTICLIMACT *-* ***MULTI****-faceted* ***CLI****Mate adaptation* ***ACT****ions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales*

- **Parole chiave:**

Multi-hazard resilience assessment; Disaster risk reduction; Climate change adaptation; Cutting-edge and cost-effective materials and digital solutions; Human health and well-being.

- **Nome e cognome del/della Responsabile della ricerca:**

Andrea Dall'Asta, Michele Morici, Università degli studi di Camerino UNICAM, EDU, Italy;

Università Politecnica delle Marche UNIVPM, EDU, Italy;

Universitaetsklinikum Aachen, UKA, EDU, Germany;

Live Information System Srl LIS SME Italy;

Comune di Camerino, CAM, GOV, Italy;

No. Participant organization name Short name Org. type Country;

Rina Consulting S.p.A., RINA-C, LE, Italy;

Agenzia Nazionale Per Le Nuove Tecnologie, L'energia E Lo Sviluppo Economico Sostenibile, ENEA, RTO, Italy;

Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, CMCC, RTO, Italy;

European Secretariat GmbH, ICLEI EURO, SME, Germany;

Steinbeis Innovation gGmbH, STEINBEIS, RTO, Germany;

fibrisTerre Systems GmbH, FIBRISTERRE, SME, Germany;

Technische Universiteit Delft, TUDELFT, EDU, Netherlands;

FUNDACION TECNALIA RESEARCH & INNOVATION TEC, RTO, Spain;

COMSA S.A.U. COMSA, LE, Spain;

CYPE Software SL, CYPE, SME Spain;

BRIGAID CONNECT BRC, NGO, Spain;

Naturalea Conservació SL, NATURALEA, SME, Spain;

AJUNTAMENT DE BARCELONA, BCN, GOV, Spain;

KTH Royal Institute of Technology, KTH, EDU, Sweden;

UPONOR Corporation, UPONOR, LE, Finland;

UPONOR AB, UPO (SE), LE, Sweden;

Riga Municipal Agency "Riga Energy Agency", REA, GOV, Latvia;

National Center for Scientific Research Demokritos, NCSRD, RTO, Greece;

Universidade do Minho, UMINHO, EDU, Portugal;

Hoogheemraadschap van Delfland, DELFLAND, GOV, Netherlands;

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UNIVERSITÀ DI CAMERINO

MODULO 1

Waterschap Limburg, WL, GOV, Netherlands;

- **Conflitto di interessi:**

Insussistenza di situazioni di incompatibilità e condizioni di conflitto di interessi.

- **Promotore della Ricerca:**

UNIONE EUROPEA.

Call: HORIZON-CL5-2022-D4-02 (Efficient, sustainable and inclusive energy use)

Topic: HORIZON-CL5-2022-D4-02-01: Designs, materials and solutions to improve resilience, preparedness & responsiveness of the built environment for climate adaptation

Type of Action: HORIZON-IA

- **Sinossi in lingua italiana del progetto di ricerca:**

Il rapporto IPCC 2022 sottolinea il legame tra cambiamento climatico causato dall'uomo e i crescenti rischi per ambiente e popolazione. È urgente non solo contenere il riscaldamento globale entro 1,5°C, ma anche promuovere strategie di adattamento efficaci e uno sviluppo resiliente al clima, come previsto dalla strategia UE per un'Europa resiliente entro il 2050.

L'ambiente costruito (edifici, infrastrutture, centri urbani, patrimonio culturale) è particolarmente vulnerabile ai cambiamenti climatici e spesso aumenta, anziché ridurre, la fragilità delle persone. Serve quindi un ripensamento della sua progettazione e gestione.

Il progetto MULTICLIMACT intende supportare enti pubblici e cittadini nel rafforzare la resilienza dell'ambiente costruito e delle persone, attraverso soluzioni innovative, digitali e sostenibili, adattabili a diversi contesti.

Con l'80% delle città globali già esposte a gravi rischi climatici (ondate di calore, alluvioni, siccità), è necessario un approccio integrato e multiscala, che tenga conto dei rischi locali e del ciclo di vita degli edifici.

MULTICLIMACT promuove una resilienza integrata umano-ambiente, basata su soluzioni per migliorare la preparazione (ad esempio attraverso una pianificazione consapevole e la progettazione degli edifici, nonché sistemi di monitoraggio affidabili), la capacità di risposta (come sistemi di early-warning e materiali e tecnologie ad alte prestazioni) e la capacità di recupero.

Il progetto prevede quattro siti dimostrativi in diversi contesti europei e mira a coinvolgere attivamente le comunità locali e i decisori politici, offrendo strumenti replicabili per affrontare le sfide climatiche e sociali. Fondamentale è il ruolo attivo delle persone, spesso percepite come soggetti passivi.

MULTICLIMACT promuove un concetto innovativo di resilienza integrata tra esseri umani e ambiente costruito, che considera salute, aspetti sociali ed economici, e valorizza il coinvolgimento diretto dei cittadini nella protezione e nella gestione degli spazi in cui vivono e lavorano.

Il progetto propone un approccio replicabile e integrato per affrontare molteplici rischi climatici e naturali (ondate di calore, alluvioni, siccità, terremoti)

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applicabile a diverse scale (dal singolo edificio fino al territorio). Saranno sviluppate e dimostrate soluzioni innovative, ad alto livello di maturità tecnologica (TRL), in quattro siti pilota rappresentativi di differenti zone climatiche, contesti sociali ed economici dell'Unione Europea, inclusi siti di interesse culturale.

Ogni elemento dell'ambiente costruito può rappresentare sia un punto di fragilità sia un'opportunità di protezione. Il progetto sottolinea inoltre come le persone non siano semplici spettatori delle conseguenze dei disastri, bensì attori fondamentali della resilienza. Il coinvolgimento attivo dei cittadini è essenziale per garantire l'efficacia degli interventi.

Per questo motivo, MULTICLIMACT promuove un nuovo concetto di resilienza integrata umano-ambiente costruito, che tenga conto anche di aspetti sanitari, sociali ed economici nella valutazione della resilienza. Questo approccio richiede l'elaborazione di nuovi metodi di valutazione e strumenti che possano supportare le amministrazioni locali nella formulazione di politiche efficaci e nella pianificazione di azioni centrate sull'uomo, ma anche nell'empowerment delle comunità per affrontare consapevolmente i rischi.

Obiettivi Principali

MULTICLIMACT intende sviluppare un quadro metodologico e uno strumento di supporto decisionale per valutare la resilienza dell'ambiente costruito e delle persone su più scale (edifici, aree urbane, infrastrutture), rispetto ai rischi climatici e naturali locali. Il progetto fornirà strumenti per migliorare la preparazione e la capacità di risposta durante l'intero ciclo di vita dell'ambiente costruito.

Verrà inoltre sviluppato un sistema di valutazione della resilienza (scorecard) che includa elementi fisici e umani (salute, benessere, qualità della vita), assieme a un kit di strumenti pratici (progettazione, materiali, soluzioni digitali) che consenta di stimare in modo semplice l'impatto delle soluzioni proposte.

L'obiettivo generale del progetto è, dunque, fornire un metodo replicabile, uno strumento operativo e un kit di soluzioni per valutare e rafforzare la resilienza dell'ambiente costruito e delle persone. MULTICLIMACT affronta molteplici rischi su più livelli e integra un approccio multidisciplinare e sistemico attraverso un insieme di azioni adattative innovative.

- **Copertura assicurativa:**

Non è prevista una ulteriore copertura assicurativa in aggiunta e/o sostituzione alla polizza assicurativa prevista dall'ateneo. Nella sperimentazione non vi sono problemi di sicurezza in relazione ai test, in quanto i partecipanti non saranno esposti a condizioni diverse dalle loro normali condizioni di lavoro (attività di studio, lettura di documenti, lavoro al computer, ecc..).

- **Tipologia di ricerca:**

L'obiettivo di questo studio pilota è sviluppare una metodologia per misurare in modo olistico il benessere delle persone nell'ambiente costruito, utilizzando

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sensori fisiologici indossabili e sensori ambientali, valutando al contempo l'esperienza soggettiva degli occupanti tramite questionari.

La ricerca prevede una campagna sperimentale durante la quale i partecipanti saranno esposti a diverse condizioni termiche tipiche delle varie stagioni. Verrà chiesto loro di compilare questionari riguardanti la percezione termica, il comfort e lo stato emotivo, mentre verranno acquisiti i loro segnali fisiologici (ad esempio, segnale fotopletismografico, segnale elettrocardiografico, saturazione di ossigeno nel sangue, temperatura della pelle, ecc.). I dati saranno analizzati in correlazione con i parametri ambientali rilevati. I risultati potrebbero essere rilevanti sia per l'ottimizzazione del benessere e dell'efficienza produttiva nell'ambiente costruito, sia per il miglioramento del consumo energetico degli edifici.

- **Popolazione in studio**:

Per la sperimentazione si prevede il reclutamento di 30 soggetti volontari (età ≥18 anni), facenti parte della comunità dell'Università di Camerino (Docenti, Ricercatori, Studenti, Personale Amministrativo, ecc..) ed i soggetti coinvolti nel progetto di ricerca MULTICLIMACT. Non sono previsti criteri specifici di esclusione per i soggetti ricadenti nella categoria precedentemente individuata. Gli scenari di test prevedranno la presenza di un massimo di 4 soggetti all'interno delle stanze per ciascuna sessione di prova.

L'acquisizione del consenso da parte dei soggetti avverrà attraverso un apposito modulo di consenso informato.

Tutti i segnali saranno acquisiti in modo sincrono tramite la stessa piattaforma, sviluppata da LIS (Live Information System, uno spin-off dell'UNIVPM e partner del progetto MULTICLIMACT), nella quale sono stati integrati tutti i sensori. Ciascun soggetto verrà identificato nel sistema mediante un'opportuna codifica. Ciascun soggetto potrà accedere esclusivamente ai proprio dati.

I risultati dei dati saranno resi disponibili nella piattaforma solo sotto forma di dati aggregati (media, deviazione standard, e così via...) al fine di garantire la privacy di ciascuna soggetto coinvolto nel test.

- **Intervento sulla popolazione in studio**:

Lo studio prevede l'acquisizione e la misurazione dei segnali fisiologici (ad esempio, segnale fotopletismografico, segnale elettrocardiografico, saturazione di ossigeno nel sangue, temperatura della pelle, ecc.) dei soggetti, utilizzando sensori fisiologici indossabili e sensori ambientali. I sensori indossabili saranno posizionati sul polso non dominante di ciascun partecipante. Gli scenari di test prevedranno la presenza di un massimo di 4 soggetti all'interno delle stanze di prova, i cui segnali fisiologici saranno acquisiti simultaneamente tramite sensori personali – Emotibit. I sensori ambientali saranno installati in un'unica posizione nella stanza (ad esempio, su una scrivania). Per i test verranno utilizzate due

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Università di Camerino

MODULO 1

stanze "gemelle", situate al primo piano dell'edificio delle Carmelitane, a Camerino, Italia.

Ciascuna sessione di test avrà una durata di 90 minuti, durante i quali al soggetto sarà consentito scegliere liberamente l'attività da svolgere. Durante la sessione, sarà effettuata la valutazione dell'esperienza soggettiva della percezione termica, del comfort e dello stato emotivo tramite un questionario dedicato compilato da ciascun soggetto a intervalli regolari di 15 minuti (secondo le scale ASHRAE, con valutazioni a 5 punti per la sensazione, la preferenza e la soddisfazione multidominio, nonché per l'affettività), al fine di fornire indici della percezione e del comfort multidominio.

Tutti i segnali saranno acquisiti in modo sincrono tramite la stessa piattaforma, sviluppata da LIS (Live Information System, uno spin-off dell'UNIVPM e partner del progetto MULTICLIMACT), nella quale sono stati integrati tutti i sensori.

- **Durata dell'intero progetto e delle eventuali fasi**:

I test inizieranno a luglio e potranno svolgersi fino alla fine dell'intero progetto (31/03/2027).

Ciascuna sessione del test avrà una durata di 90 minuti a si svolgeranno nell'arco di due settimane.

Il test sarà ripetuto sia in estate che in inverno.

- **Dichiarazione di impegno a comunicare cambiamenti della sperimentazione**:

Comunicazione da fare per iscritto al Comitato Etico di qualunque cambiamento che potrà intervenire nel corso della sperimentazione al fine di ottenere ulteriore parere positivo da parte del Comitato e di trasmettere allo stesso una comunicazione di fine sperimentazione.

- ☒ *Sì, mi impegno*
- ☐ *No, non mi impegno*

Data
Firma del/della Responsabile della ricerca
04/06/2024

____

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MODULO 2

Foglio informativo

Titolo dello studio: MULTICLIMACT – MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales.

Task 11.1: Demonstration of the MULTICLIMACT framework at the building scale

Protocollo: Test_protocol_MULTICLIMACT_DEF.pdf

Struttura dove si effettua la sperimentazione: Edificio ex Convento Carmelitane - via Viviano Venanzi 16, Camerino (MC).

Responsabile della ricerca

Clemente Fuggini - RINA Consulting S.p.A. (Project Coordinator)

Andrea Dall'Asta - Scuola di Scienza e Tecnologia, Università di Camerino (P.I. UNICAM)

Michele Morici - Scuola Architettura e Design, Università di Camerino (UNICAM)

Ricercatori Associati

Valeria Leggieri - Scuola Architettura e Design, Università di Camerino (UNICAM)

Gloria Cosoli - Università Telematica eCampus, Faculty of Engineering (UNIVPM)

Francesca Tittarelli, Alessandra Mobili - Università Politecnica delle Marche, Facoltà di Ingegneria (UNIVPM)

Victoria Blessing - Steinbeis Innovation gGmbH (Steinbeis)

Marta Rivarola, Eva Raggi, Cristina Vaccarella - RINA Consulting S.p.A. (RINA-C),

Nensi Lalaj - BRIGAID CONNECT (BRC)

Lucia Barchetta – Comune di Camerino (CAM)

Rifat Seferi - Live Information System Srl (LIS)

Marcel Schweiker - Universitaetsklinikum Aachen (UKA)

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MODULO 2

Gentile Signora / Egregio Signore,

Le è stato chiesto di partecipare ad uno studio per misurare il benessere delle persone nell'ambiente costruito, utilizzando sensori fisiologici indossabili e sensori ambientali e valutando l'esperienza soggettiva degli occupanti tramite questionari dal titolo MULTICLIMACT – MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales, Task 11.1: Demonstration of the MULTICLIMACT framework at the building scale.

Questo documento ha lo scopo di informarLa, in modo corretto e completo, sulla natura e sui fini dello studio; su quanto le sarà chiesto di fare nel caso in cui decida di prendervi parte; sui Suoi diritti e sulle Sue responsabilità.

Le chiediamo di leggere attentamente queste informazioni scritte, per poter assumere una determinazione libera e consapevole in merito ad una Sua eventuale partecipazione allo studio.

Lo sperimentatore ed i suoi collaboratori sono disponibili a fornire ogni chiarimento ed ogni informazione ulteriore rispetto a quanto riportato di seguito.

Nel caso in cui, dopo aver letto e compreso tutte le informazioni ivi fornite, decidesse di voler partecipare allo studio, Le sarà chiesto di firmare e personalmente datare il modulo di Consenso Informato allegato a questo documento.

INFORMAZIONI SULLE PROCEDURE DI TEST

L'attività in cui il soggetto è coinvolto è destinata alla sperimentazione e dimostrazione del framework del progetto europeo MULTICLIMACT (MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales) e delle soluzioni tecnologiche sviluppate, presso il sito dimostrativo italiano.

MULTICLIMACT è un Horizon Europe project finanziato dalla European Commission (grant agreement No 101123538); maggiori informazioni sono disponibili al link: https://multiclimact.eu/.

Il task T11.1 del progetto MULTICLIMACTè dedicato alla sperimentazione e dimostrazione del framework MULTICLIMACT e delle soluzioni tecnologiche sviluppate, presso il sito dimostrativo italiano. La sperimentazione al livello di singolo edificio comprenderà la sperimentazione di tutte le soluzioni del toolkit MULTICLIMACT sviluppate nei task T8.5, T9.3, T10.2.

Il processo di sperimentazione è svolto in stretta collaborazione tra gli stakeholder pubblici/leads del demo, owero l'Università di Camerino (UNICAM) e il Comune di Camerino (CAM), insieme ai partner responsabili dello sviluppo delle soluzioni del toolkit da testare nel sito italiano.

Gli obiettivi della sperimentazione nel caso pilota comprendono:

- **Lo sviluppo di un quadro di valutazione completo** per il benessere fisico, mentale e sociale, basato su indicatori chiave di prestazione (KPI) definiti nella fase precedente del progetto. Questo quadro è pensato per essere applicato nel dimostratore italiano e fornisce un approccio strutturato per valutare in che modo le progettazioni dell'ambiente costruito influenzino la salute umana in molteplici dimensioni. Esso si basa su KPI predefiniti per garantire coerenza e misurabilità, costituendo la base per le valutazioni successive.
- **La progettazione di un protocollo di studio completo** che incorpori misure di valutazione soggettive e oggettive. Questo protocollo mira a valutare l'efficacia delle soluzioni progettuali implementate, combinando dati soggettivi (ad es. comfort

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multidimensionale e percezioni degli occupanti) con dati oggettivi (ad es. parametri fisiologici e ambientali), nonché con dati fisiologici individuali (ad es. segnali di attività elettrodermica (EDA) e temperatura cutanea). Questo approccio consente una valutazione olistica degli esiti relativi al benessere.

- **L'elaborazione di un esempio di buona pratica.** Sulla base dei risultati del quadro di valutazione e del protocollo di studio, questo obiettivo si concentra sulla creazione di un esempio di buona pratica che dimostri l'applicazione efficace dei principi del design centrato sulla persona. Tale esempio fungerà da guida pratica per progetti futuri, illustrando strategie efficaci per migliorare salute e benessere in contesti simili.
- **Di confrontare** attraverso le misurazioni ambientali e fisiologiche il benessere delle persone all'interno degli ambienti (T10.2) nei quali sono stati implementati differenti interventi di riqualificazione energetica (impiego di soluzioni tradizionali o soluzioni naturali sviluppati all'interno del T9.3 del progetto).

Gli occupanti dell'edificio Carmelitane saranno direttamente coinvolti nella sperimentazione delle soluzioni MULTICLIMACT, attraverso l'utilizzo del protocollo e del sistema di monitoraggio definiti nei punti successivi, elaborati per valutare il comfort termico e il benessere degli occupanti. A tal fine, saranno utilizzate analisi avanzate dei dati e una rete distribuita di sensori, che verranno installati con l'obiettivo di aumentare la consapevolezza degli utenti riguardo allo stato di salute strutturale, al comfort termico e all'efficienza energetica, oltre a generare allerte precoci, migliorando così la resilienza dell'edificio e degli individui.

I dati acquisiti dal sistema di monitoraggio ambientale e personale saranno gestiti in tempo reale dalla piattaforma LIS, la quale sarà connessa con i dati dei sensori provenienti dall'infrastruttura IoT. Sulla base dei dati reali, la piattaforma sarà in grado di analizzare e confrontare scenari futuri e modelli matematici teorici sviluppati dai partner, relativi a indicatori di efficienza energetica, qualità ambientale interna, salute e benessere degli occupanti, e stato di salute strutturale in caso di sisma. I sensori saranno selezionati tenendo conto del loro posizionamento ottimale e dei metodi di analisi dei dati in relazione alle sollecitazioni ambientali. Verranno considerati diversi approcci, dai metodi basati sui dati ai modelli aggiornati. Sarà inoltre sviluppata una piattaforma di analisi dei dati come archivio pubblico accessibile a tutti i partner, in modo che i dati possano essere recuperati e processati da ciascuno. I dati saranno analizzati automaticamente e raggruppati utilizzando l'algoritmo di clustering k-means.

I partecipanti saranno esposti a diverse condizioni termiche tipiche delle stagioni dell'anno. Verrà chiesto loro di compilare questionari riguardanti la loro percezione termica, il comfort e il loro stato emotivo, mentre verranno acquisiti i loro segnali fisiologici (ad esempio, segnale fotopletismografico, segnale elettrocardiografico, saturazione di ossigeno nel sangue, temperatura della pelle, ecc.). I dati saranno analizzati in correlazione con i parametri ambientali rilevati. Questi risultati sono potenzialmente rilevanti sia per l'ottimizzazione del benessere che per il miglioramento della produttività nell'ambiente costruito, oltre che per il miglioramento del consumo energetico degli edifici.

L'analisi avanzata dei dati sarà utilizzata per finalità di classificazione e previsione in termini di sensazione termica, nonché per l'ottimizzazione del funzionamento degli impianti HVAC, con conseguente riduzione dei consumi energetici dell'edificio e miglioramento della qualità della vita indoor e del benessere generale degli occupanti.

I test saranno eseguiti nelle due stanze selezionate presso l'edificio Carmelitane. Entrambe le stanze (stanza 1 e 2) si trovano al primo piano dello stabile e sono completamente accessibili. La stanza 1 sarà allestita

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con una configurazione "standard", utilizzando interventi di riqualificazione energetica basati su pannelli isolanti di origine petrolchimica, come il polistirene espanso (EPS) e il polistirene estruso (XPS), comunemente impiegati nei tradizionali interventi edilizi. La stanza 2, invece, sarà dotata di un allestimento che prevede l'impiego di materiali/prodotti innovativi di origine naturale e locale, come pannelli in fibra di canapa, anch'essi disponibili sul mercato. In aggiunta, in una parete della stanza 2 sarà applicata una malta multifunzionale sviluppata nei T3.3 e T9.3 del progetto e destinata al miglioramento della qualità dell'aria interna (IAQ – Indoor Air Quality) e della qualità della vita (QoL – Quality of Life) degli occupanti, oltre che dei sistemi basati su materiali self-sensing per il monitoraggio strutturale e sismico.

Selezione dei partecipanti

Per la sperimentazione si prevede il reclutamento di 30 soggetti volontari (età ≥18 anni), facenti parte della comunità dell'Università di Camerino (Docenti, Ricercatori, Studenti, Personale Amministrativo, ecc..) ed i soggetti coinvolti nel progetto di ricerca MULTICLIMACT. Anche se il numero di partecipanti coinvolti possa sembrare non molto esteso, tuttavia può essere considerato sufficiente per validare la metodologia proposta per il caso pilota in condizioni reali.

Procedure Sperimentali

La procedura prevede una sessione di test della durata di circa 90 minuti, durante la quale il partecipante può svolgere liberamente attività di sua scelta, come leggere o lavorare al computer, proprio come farebbe in una normale giornata lavorativa. L'obiettivo è osservare il comportamento e il comfort del soggetto in condizioni quotidiane, senza modificare intenzionalmente l'ambiente circostante. La sessione viene ripetuta in entrambe le stanze selezionate (stanza 1 e 2) che prevedono l'implementazione delle due differenti soluzioni.

Durante il test, ogni 15 minuti a partire dal quindicesimo minuto iniziale, viene somministrato un questionario per registrare l'attività svolta e raccogliere informazioni sul comfort percepito. I questionari, basati sulle scale ASHRAE, utilizzano una valutazione a 5 punti per misurare la sensazione, la preferenza, la soddisfazione e lo stato affettivo legati a più domini ambientali. I dati raccolti consentono di calcolare indici di percezione e comfort multidominio.

Nel corso del test, ai partecipanti è richiesto di portare con sé il proprio laptop o un libro. Sono inoltre consentite le normali operazioni di ventilazione (come l'apertura delle finestre) e l'utilizzo di dispositivi personali per il comfort, come ventilatori o stufette, in base alla stagione.

Oltre alla valutazione sulla esperienza soggettiva degli occupanti tramite la somministrazione dei questionari, saranno effettuate delle misure sulle condizioni ambientali e fisiologiche dei soggetti partecipanti utilizzando sensori fisiologici indossabili (acquisizione del segnale fotopletismografico – PPG –, attività elettrodermica – EDA –, temperatura cutanea e segnali relativi al movimento).

I sistemi e le metodologie di acquisizione includono:

- **Emotibit [1]**, un sensore indossabile multidominio (smartband) in grado di raccogliere segnali EDA, temperatura cutanea, segnale PPG, umidità e temperatura, nonché segnali relativi al movimento (attraverso giroscopio, accelerometro e magnetometro).
- **Sensore DomX** (DomX IoT technologies, Salonicco, Grecia), un sistema di misurazione ambientale multidominio che include sensori per la valutazione della qualità dell'aria interna: temperatura (°C), umidità relativa (%), pressione atmosferica (Pa), PM1, PM2.5 e PM10 (μg/m^3), CO_2 (ppm), VOC respiratori (ppm) e illuminamento (lux).

- **Questionari** su informazioni demografiche e personali, comfort multidominio, affettività positiva e negativa (PANAS) e livello di abbigliamento.

I sensori indossabili verranno indossati sul polso non dominante dei partecipanti. I sensori ambientali saranno posizionati in un punto unico nella stanza (ad esempio su una scrivania). Inoltre, per valutare l'effetto di un pannello isolante a base di malta multifunzionale (brevettata da UNIVPM) volto a migliorare la qualità dell'aria interna (IAQ)

L'intero test viene eseguito tramite la piattaforma LIS, grazie alla sua precedente implementazione nel sistema digitale, che consente non solo la somministrazione dei questionari, ma anche la raccolta e la sincronizzazione dei dati provenienti da sensori differenti, in scenari multi-occupante (fino a 4 soggetti monitorati contemporaneamente).

Analisi dei dati

I dati acquisiti saranno elaborati sia con algoritmi integrati nella piattaforma di acquisizione sia con altri sviluppati in ambiente MATLAB/Python. L'obiettivo dell'elaborazione è correlare le quantità fisiologiche con i parametri ambientali e con i risultati dei questionari, al fine di sintetizzare indici relativi al benessere e alla salute dei soggetti. Inoltre, tecniche di Intelligenza Artificiale e Apprendimento Automatico, così come modelli termo-fisiologici esistenti, potranno essere applicati anche per finalità predittive su diverse variabili, sia ambientali (ad es. temperatura e umidità relativa), sia soggettive (ad es. frequenza cardiaca o indici di salute/benessere). Queste informazioni potranno essere utilizzate per il controllo termo-igrometrico dell'ambiente costruito, con l'obiettivo di ottimizzare sia il benessere degli occupanti che il consumo energetico dell'edificio. Inoltre, gli indici di salute e benessere verranno integrati nel modello BIM dell'edificio.

Benefici dei partecipanti alla ricerca

Attraverso l'analisi approfondita ed avanzata dei dati acquisiti dal sistema di monitoraggio, sarà possibile effettuare la classificazione e la previsione della sensazione termica percepita dagli occupanti, nonché ottimizzare il funzionamento degli impianti di climatizzazione HVAC (Heating, Ventilation and Air Conditioning). Questo consentirà una riduzione dei consumi energetici dell'edificio e un miglioramento della qualità della vita indoor e del benessere generale degli utenti.

Responsabilità dei partecipanti alla ricerca

Ogni partecipante alla presente ricerca è responsabile di:
Integrità dei dati forniti: Fornire risposte accurate e sincere ai quesiti, assicurandosi di comprendere le domande e di dare risposte pertinenti.
Diritto di rifiuto: Rifiutare di partecipare alla ricerca o di rispondere a specifiche domande senza dover fornire una motivazione.
Comunicazione: Comunicare al ricercatore qualsiasi dubbio o apprensione riguardo alla ricerca.

Rischi

Nella sperimentazione non vi sono problemi di sicurezza in relazione ai test, in quanto i partecipanti non saranno esposti a condizioni diverse dalle loro normali condizioni di lavoro.

Obbligo di riservatezza

Nessuna informazione identificativa sarà inserita nei moduli compilati. I dati acquisiti saranno gestiti dai responsabili della piattaforma in accordo con quanto previsto dalla legge sulla privacy (Legge n. 675 del 31 dicembre 1996). Per garantire una maggiore tutela saranno adottate le seguenti misure:

- Assegnazione di codici o numeri identificativi anonimi ai partecipanti, che saranno utilizzati per l'intera durata dello studio.
- Nessuna conservazione di appunti, trascrizioni di interviste o altre informazioni che possano identificare il partecipante.

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I dati dei partecipanti saranno mantenuti riservati, salvo nei casi in cui il gestore dell'archivio sia legalmente obbligato a segnalare determinati eventi che violino le leggi vigenti.
La informiamo che questo studio è stato sottoposto al parere del Comitato Etico della Ricerca di UNICAM.
Durante lo studio, Lei potrà contattare il Responsabile per qualsiasi utile informazione.

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MODULO 2

DICHIARAZIONE DEL RESPONSABILE DELLO STUDIO

Dichiaro di aver fornito al/alla partecipante informazioni complete, comprensibili e dettagliate circa la natura, lo scopo, le procedure e la durata dello studio. Dichiaro di aver verificato che il/la partecipante abbia adeguatamente compreso le informazioni fornite e di aver lasciato al/alla medesimo/a il tempo necessario per determinarsi liberamente e consapevolmente. Dichiaro, inoltre, di aver fornito al/alla partecipante il foglio informativo allegato.

Data

Firma del/della Responsabile della ricerca o suo delegato

FIRMA DEL PARTECIPANTE SULL'INFORMATIVA

Dichiaro di aver ricevuto informazioni che mi hanno consentito di comprendere lo studio anche alla luce degli ulteriori chiarimenti da me richiesti. Confermo che mi è stata consegnata copia del presente foglio informativo.

Data

Firma del partecipante

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MODULO DI CONSENSO INFORMATO

Io sottoscritto/a Fare clic o toccare qui per immettere il testo. nato/a Fare clic o toccare qui per immettere il testo. il Fare clic o toccare qui per immettere il testo. residente a Fare clic o toccare qui per immettere il testo. Via Fare clic o toccare qui per immettere il testo. Tel. Fare clic o toccare qui per immettere il testo. Domicilio (se diverso dalla residenza) Fare clic o toccare qui per immettere il testo.

DICHIARO

- di aver ricevuto spiegazioni esaurienti in merito alla richiesta di partecipazione allo studio in oggetto, secondo quanto riportato nel foglio illustrativo ivi allegato, del quale mi è stata consegnata copia;
- di aver compreso la natura, le finalità, le procedure, i benefici attesi, gli eventuali rischi dello studio e le alternative ad esso possibili;
- di aver potuto discutere le informazioni ricevute, di aver potuto porre tutte le domande che io abbia ritenuto necessarie e di aver ricevuto in merito risposte soddisfacenti;
- di aver avuto tutto il tempo necessario di prima di decidere se partecipare o meno allo studio;
- di essere stato informato del mio diritto di ritirarmi dallo studio in qualsiasi momento.

Pertanto, alla luce delle informazioni che mi sono state fornite

MODULO 2

☐ **ACCONSENTO**	☐**NON ACCONSENTO**	a partecipare allo studio
☐ **ACCONSENTO**	☐ **NON ACCONSENTO**	ad essere informato/a sui risultati dello studio

Data

Firma del partecipante ______________________

Data

Firma del Responsabile della ricerca o suo delegato ______________

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MODULO 3

Informativa in materia di trattamento dei dati personali

Gentile Signore/a,
ai sensi delle norme di legge in materia di protezione dei dati personali, ed in particolare del Regolamento (UE) 2016/679 (di seguito GDPR), del D.lgs. 30 giugno 2003, n. 196 (Codice in materia di protezione dei Dati Personali) come novellato dal D.lgs. 10 agosto 2018, n. 101, delle Linee Guida per i trattamenti di dati personali nell'ambito delle sperimentazioni cliniche di medicinali di cui alla Deliberazione del Garante Privacy n. 52 del 24 luglio 2008 - G.U. n. 190 del 14 agosto 2008, La informiamo che il trattamento dei dati personali e delle informazioni che la riguardano, raccolti nel corso del presente studio, sarà improntato al rispetto dei diritti e delle libertà fondamentali, nonché ai principi di correttezza, liceità, trasparenza, minimizzazione, esattezza, integrità e riservatezza.

In ossequio alle prescrizioni normative vigenti, precisiamo inoltre quanto segue:

- (Soggetti del trattamento) Il Titolare del trattamento, che determina le finalità ed i mezzi del trattamento dei suoi dati personali, è Rifat Seferi, per conto della Live Information System S.r.l, LiS DIISM-UNIVPM Ancona Italy, Mobile: +39 3486577647, Email: admin@liveinformation.systems, Website: liveinformation.systems
- Il Responsabile del trattamento dei dati è Rifat Seferi, per conto della Live Information System S.r.l, LiS DIISM-UNIVPM Ancona Italy, Mobile: +39 3486577647, Email: admin@liveinformation.systems, Website: liveinformation.systems
- Il Responsabile della Protezione dei dati è Rifat Seferi, a nome della Live Information System S.r.l, LiS DIISM-UNIVPM Ancona Italy, Mobile: +39 3486577647, Email: admin@liveinformation.systems, Website: liveinformation.systems
- (Definizione di 'trattamento' e di 'dati personali') Il trattamento avrà ad oggetto i Suoi dati personali comuni (nome, cognome, data di nascita) e particolari (dati relativi alla Sua salute, alla Sua origine, ai Suoi stili di vita, alla Sua vita sessuale. [indicare tipologia dei dati raccolti]) ed avverrà solo Suo previo, specifico ed esplicito consenso
- (Natura del conferimento dei dati e conseguenze in caso di eventuale rifiuto) I dati liberamente conferiti saranno utilizzati solo per lo scopo di studio e ricerca previsto dal progetto e nella misura in cui essi siano indispensabili in relazione all'obiettivo scientifico perseguito. Il conferimento dei dati è facoltativo e l'eventuale rifiuto a fornirli potrà comportare solo l'interruzione della Sua partecipazione allo studio [oppure dichiarare la diversa modalità del conferimento]
- (Modalità di trattamento) I dati personali saranno raccolti, gestiti e custoditi sia in formato cartaceo che elettronico e/o automatizzato (specificare in modo dettagliato le modalità utilizzate nel caso specifico). In ogni caso saranno adottate tutte le procedure idonee a proteggerne la riservatezza, nel rispetto delle norme vigenti e del segreto professionale
- (Periodo di conservazione) I dati personali raccolti verranno conservati per il tempo strettamente necessario al conseguimento

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delle finalità per le quali sono stati raccolti ovvero per il diverso tempo richiesto dalla legge // e comunque per un tempo non superiore a ______ indicare precisamente il numero di anni. I dati personali che non siano più necessari, o per i quali non vi sia più un presupposto giuridico per la relativa conservazione, verranno anonimizzati irreversibilmente o distrutti in modo sicuro

- (Comunicazione dei dati; trasferibilità o meno dei dati all'estero) I dati non verranno comunicati o diffusi // OPPURE e verranno diffusi solo in forma rigorosamente anonima (indicare come – ad esempio attraverso pubblicazioni scientifiche, statistiche e convegni – e quali sono eventuali destinatari se noti) // qualora si renda necessario il trasferimento dei dati in Paesi extra UE o a organizzazioni internazionali occorre fornire una informazione specifica e nel caso in cui nel Paese di destinazione non sia stata adottata una previsione di adeguatezza o non siano state approntate adeguate garanzie di protezione, occorre richiedere il consenso specifico al trasferimento
- (Diritti dell'interessato) In qualità di soggetto interessato, Lei potrà esercitare in qualsiasi momento i diritti previsti dagli artt. 15-22 del GDPR. In particolare potrà richiedere a ciascun Titolare del trattamento di accedere ai Suoi dati personali, verificarne contenuto, origine, esattezza, ubicazione (anche in relazione ai Paesi Terzi ove i dati si trovino e/o ai soggetti cui i dati possono essere comunicati); potrà opporsi al loro trattamento, chiederne copia, integrazione, aggiornamento, rettifica; nei casi previsti dalla Legge vigente, potrà inoltre chiederne la cancellazione, la trasformazione in forma anonima, la limitazione, la portabilità.
- (Strumenti di tutela dell'interessato) Per esercitare i Suoi diritti, può rivolgersi al Titolare del trattamento ai recapiti sopra indicati. È altresì possibile inoltrare i propri reclami o le proprie segnalazioni all'Autorità responsabile della protezione dei dati, utilizzando gli estremi di contatto pertinenti: Garante per la protezione dei dati personali - piazza di Montecitorio n.121 - 00186 ROMA - fax: (+39) 06.696773785 - telefono: (+39) 06.696771 PEO: garante@gpdp.it - PEC: protocollo@pec.gpdp.it

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CONSENSO AL TRATTAMENTO DEI DATI

Il/La sottoscritto/a (nome e cognome) Fare clic o toccare qui per immettere il testo. nato/a a Fare clic o toccare qui per immettere il testo. il Fare clic o toccare qui per immettere il testo. Codice Fiscale Fare clic o toccare qui per immettere il testo. residente a Fare clic o toccare qui per immettere il testo. (Prov.) Fare clic o toccare qui per immettere il testo. (indirizzo) Fare clic o toccare qui per immettere il testo. domiciliato in (se il domicilio è diverso dalla residenza) Fare clic o toccare qui per immettere il testo.

(in caso di tutela o rappresentanza: consapevole delle sanzioni penali previste dall'art. 76 del D.P.R. 445/2000 per le ipotesi di falsità in atti e dichiarazioni mendaci in qualità di:

- ☐Tutore
- ☐Amministratore di sostegno
- ☐Esercente la responsabilità genitoriale
- ☐Altro ______________________

di (nome e cognome) Fare clic o toccare qui per immettere il testo. nato/a a Fare clic o toccare qui per immettere il testo. il Fare clic o toccare qui per immettere il testo. Codice Fiscale Fare clic o toccare qui per immettere il testo. residente a Fare clic o toccare qui per immettere il testo. (Prov.) Fare clic o toccare qui per immettere il testo. (indirizzo) Fare clic o toccare qui per immettere il testo.

Letta e compresa l'informativa di cui all'Art. 13 del Regolamento (UE) 2016/679 e consapevole del diritto di revocare il consenso in qualsiasi momento ai sensi dell'art. 7 del GDPR, ferma restando impregiudicata la liceità del trattamento basata sul consenso prestato prima della revoca:

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al trattamento dei dati personali, comuni e particolari, necessari per lo svolgimento dello studio/progetto di ricerca nei limiti e con le modalità indicate nell'informativa fornita con il presente documento

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alla comunicazione al/alla sottoscritto/a dei risultati della ricerca, (OVE APPLICABILE)

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al trasferimento dei dati personali, anche particolari, al di fuori dell'Unione Europea (specificare gli estremi identificativi dei destinatari), - in Paesi che non garantiscono un adeguato livello di protezione dei dati personali secondo la normativa europea - per gli scopi di ricerca ma nei limiti e con le modalità indicate nell' informativa e sempre in forma anonima.

Data

Firma partecipante

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MODULO 4

Protocollo di Ricerca

Titolo del progetto

MULTICLIMACT - MULTI-faceted CLIMate adaptation ACTions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales.

Parole chiave

Multi-hazard resilience assessment; Disaster risk reduction; Climate change adaptation; Cutting-edge and cost-effective materials and digital solutions; Human health and well-being.

Principal Investigator

Clemente Fuggini - RINA Consulting S.p.A. (Project Coordinator)
Andrea Dall'Asta - Scuola di Scienza e Tecnologia, Università di Camerino (P.I. UNICAM)
Michele Morici - Scuola Architettura e Design, Università di Camerino (UNICAM)

Ricercatori Associati

Valeria Leggieri - Scuola Architettura e Design, Università di Camerino (UNICAM)
Gloria Cosoli - Università Telematica eCampus, Faculty of Engineering (UNIVPM)
Francesca Tittarelli, Alessandra Mobili - Università Politecnica delle Marche, Facoltà di Ingegneria (UNIVPM)
Victoria Blessing - Steinbeis Innovation gGmbH (Steinbeis)
Marta Rivarola, Eva Raggi, Cristina Vaccarella - RINA Consulting S.p.A. (RINA-C),
Nensi Lalaj - BRIGAID CONNECT (BRC)
Lucia Barchetta – Comune di Camerino (CAM)
Rifat Seferi - Live Information System Srl (LIS)
Marcel Schweiker - Universitaetsklinikum Aachen (UKA)

Informazioni dettagliate del progetto

Topic: HORIZON-CL5-2022-D4-02-01: Designs, materials and solutions to improve resilience, preparedness & responsiveness of the built environment for climate adaptation (Built4People) (IA)
Title of Proposal: MULTI-faceted **CLIM**ate adaptation **ACT**ions to improve resilience, preparedness and responsiveness of the built environment against multiple hazards at multiple scales
Proposal Acronym: **MULTICLIMACT**

MULTICLIMACT is a Horizon Europe project supported by the European Commission under grant agreement No 101123538. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them (https://multiclimact.eu/).

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MULTICLIMACT PROJECT

Il rapporto del Gruppo intergovernativo sui cambiamenti climatici (IPCC) "Climate Change 2022: Impacts, Adaptation and Vulnerability" [1] conferma il forte legame tra i cambiamenti climatici causati dall'uomo e un'ampia gamma di rischi per la natura e per le persone in tutto il mondo. In questo contesto, oltre alla necessità di limitare il riscaldamento globale a 1,5°C, è urgente coinvolgere i decisori politici e l'opinione pubblica nell'implementazione di strategie di adattamento efficaci e realizzabili, nonché favorire una transizione completa verso uno sviluppo resiliente al clima.

L'urgenza di fornire strategie climaticamente resilienti è stata affrontata dalla Commissione Europea attraverso diverse iniziative, tra cui la Comunicazione del 2021 *"Forging a climate-resilient Europe – the new EU Strategy on Adaptation to Climate Change"*, [2] che definisce una visione a lungo termine per diventare una società resiliente al clima entro il 2050. In quest'ottica, il cambiamento climatico è considerato una sfida inevitabile da affrontare attraverso:

i) una maggiore comprensione degli impatti climatici;
ii) l'adozione di azioni di adattamento più intelligenti, sistemiche e rapide.

In questo quadro, l'ambiente costruito riveste un ruolo fondamentale, poiché infrastrutture, centri urbani ed edifici (incluso il patrimonio culturale) costituiscono lo spazio in cui le persone vivono, lavorano e trascorrono il tempo libero. L'ambiente costruito è fortemente impattato dai cambiamenti climatici e più in generale, dai rischi naturali (dalle alluvioni ai terremoti), che rappresentano una minaccia diretta alla sua conservazione, rendendolo una vulnerabilità per l'intera società. I rischi climatici derivano dall'interazione tra la vulnerabilità del sistema colpito e l'esposizione al pericolo nel tempo. Poiché le condizioni climatiche sono in continuo cambiamento e i fenomeni estremi stanno diventando più frequenti, è urgente pianificare, progettare e riqualificare l'ambiente costruito affinché sia adattabile ai rischi presenti e futuri.

Troppo spesso l'ambiente costruito rappresenta un elemento di vulnerabilità anziché un rifugio per i cittadini. Per questo motivo, è fondamentale agire sia in chiave di mitigazione che di adattamento, ponendo l'ambiente costruito e la resilienza umana al centro dell'azione climatica [3].

Secondo il rapporto CDP *"Protecting People and the Planet"* (ottobre 2022) [4], basato su un questionario somministrato a città di tutto il mondo, l'80% delle città segnala rischi climatici significativi, tra cui le principali minacce sono: caldo estremo (46%), piogge intense (36%), siccità (35%) e alluvioni (33%). Questo insieme di rischi, che varia localmente e in alcuni casi è aggravato da altri fenomeni naturali come i terremoti, colpisce il complesso sistema dell'ambiente costruito, generando conseguenze interconnesse su più scale, dai singoli edifici agli spazi urbani fino alle infrastrutture territoriali.

È quindi necessario un approccio multi-scala, che integri la resilienza climatica degli edifici e delle persone nelle strategie di pianificazione urbana più ampie, rafforzando le sinergie tra la valutazione multi-rischio per la riduzione dei disastri e l'adattamento ai cambiamenti climatici. Un altro

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aspetto cruciale riguarda la rilevanza temporale degli interventi di resilienza, fortemente correlata con il ciclo di vita dell'ambiente costruito.

Migliorare la resilienza dell'ambiente costruito richiede soluzioni per potenziare:

- la preparazione (es. pianificazione consapevole, progettazione e sistemi di monitoraggio),
- la risposta (es. sistemi di allerta precoce, materiali e tecnologie performanti),
- la capacità di recupero post-evento.

Tali interventi richiederanno materiali e soluzioni digitali all'avanguardia, efficienti, disponibili e convenienti.

Durante la COP27, è stato raggiunto un accordo storico sul nuovo *Loss and Damage Fund*, indirizzando gli sforzi di mitigazione e adattamento verso investimenti finanziari, tecnologici e di rafforzamento delle capacità. Questo ha aperto la strada ai progressi della COP28 sull'*Obiettivo Globale di Adattamento*, contribuendo alla prima valutazione globale dei progressi e rafforzando l'azione di resilienza climatica.

Ogni elemento dell'ambiente costruito rappresenta sia un potenziale punto di fragilità che una risorsa protettiva, non solo per sé stesso (data l'identità culturale e il valore economico), ma soprattutto per le persone che vi abitano. Secondo il rapporto CDP, in circa un terzo delle città esposte ai rischi climatici, il 70% della popolazione è concretamente minacciata da eventi estremi e non estremi. Spesso le persone sono considerate attori passivi nell'interazione tra ambiente costruito e rischi climatici, trascurando il grande potenziale derivante dal rafforzamento della resilienza umana.

Le persone hanno invece un ruolo chiave nel determinare l'efficacia di qualsiasi intervento sul costruito, sia in termini di protezione che di qualità della vita e del lavoro. Per questi motivi, piuttosto che concentrarsi unicamente sulla resilienza dell'ambiente costruito, è necessario adottare un nuovo concetto sistemico di resilienza umano-costruito, che integri fattori umani (salute, aspetti sociali ed economici) nella valutazione della resilienza dell'ambiente costruito ai rischi climatici e naturali.

Questo approccio richiede nuovi metodi di valutazione, con l'obiettivo di supportare:

- le autorità locali nella comprensione, formulazione di politiche e allocazione delle risorse per azioni resilienti centrate sull'uomo;
- i cittadini nell'acquisizione di consapevolezza sulle sfide legate alla protezione di sé stessi e del proprio ambiente costruito lungo tutto il ciclo di vita.

L'obiettivo principale del progetto MULTICLIMACT sarà quello di supportare le autorità pubbliche ed i cittadini nella pianificazione, progettazione, implementazione e monitoraggio di soluzioni per migliorare l'ambiente costruito e la resilienza umana, rafforzando il suo ruolo protettivo rispetto ai rischi naturali e climatici. Inoltre, fornirà un approccio replicabile e multifattoriale per affrontare diversi rischi naturali e climatici (es. ondate di calore, alluvioni, siccità, terremoti), considerando rischi locali interconnessi (inclusi quelli legati alle catene di approvvigionamento) e molteplici scale, dal singolo edificio al contesto urbano e territoriale.

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Verranno sviluppate soluzioni innovative, efficienti e convenienti ad alto TRL, dimostrate in quattro siti pilota situati in differenti zone climatiche e contesti sociali, economici e culturali europei (inclusi siti del patrimonio culturale).

Il progetto MULTICLIMACT affronterà la sfida di invertire la fragilità attuale del costruito, spesso fonte di rischio, attraverso interventi di resilienza che includano l'essere umano come dimensione trasversale e integrata di un nuovo concetto di resilienza umano-costruito. Le autorità pubbliche saranno coinvolte nello sviluppo degli strumenti e delle soluzioni del progetto tramite metodi di co-creazione, mentre le comunità locali saranno attivamente coinvolte mediante processi di innovazione sociale per tutta la durata del progetto, ponendo le basi per un metodo replicabile da tutte le comunità interessate ad attivare azioni resilienti centrate sull'uomo.

Sostenere la preparazione e la capacità di risposta dell'ambiente costruito e dei suoi abitanti per garantirne la resilienza richiede un approccio coerente e replicabile, bilanciando la necessità di rispondere ai bisogni specifici locali con l'esigenza di scalare soluzioni accessibili, affidabili e rapide.

L'approccio proposto includerà un sistema di scorecard della resilienza, pensato per coprire diverse tipologie di beni dell'ambiente costruito, includendo benessere, salute e qualità della vita delle persone come dimensione essenziale di analisi e azione. MULTICLIMACT supporterà azioni di adattamento climatico e naturale attraverso un toolkit di pratiche progettuali, materiali e soluzioni digitali, che consentirà agli utenti di stimare facilmente l'impatto degli interventi sulla resilienza dei beni considerati, integrando un approccio multidisciplinare che unisce competenze socio-economiche, umanistiche, ingegneristiche e climatiche.

L'approccio sarà allineato alle principali iniziative europee e internazionali, valorizzando conoscenze e strumenti esistenti, e sarà dimostrato in quattro casi studio rappresentativi di diverse aree geografiche, rischi naturali e climatici, sistemi sociali ed economici e scale di intervento, dal singolo edificio (incluso il patrimonio culturale) ed alla scala urbana e territoriale.

STRUTTURA DEL PROGETTO

Il progetto MULTICLIMACT ha una durata di 42 mesi, è articolato in 17 Work Packages (WP) e strutturato in tre fasi principali corrispondenti a tre periodi successivi di rendicontazione. Il progetto segue un approccio metodologico articolato in quattro passaggi: *Plan and Design*, *Develop*, *Test*, *Deploy and Revise*.

Le fasi ed i relativi Work Pakage (WP) risultano essere:

FASE 1 – *Plan and Design* (Mese 1-12, WP1–WP6)

Obiettivo: Definire il quadro metodologico e progettare strumenti e soluzioni per la resilienza.

- **WP1**: Definizione del quadro di resilienza e delle caratteristiche tecniche e non tecniche. Sviluppo del metodo per lo strumento CREMA (per la valutazione della resilienza "as is" e post-intervento).
- **WP2–WP4**: Progettazione del toolkit MULTICLIMACT:

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- **WP2**: Metodi di progettazione e pianificazione (es. supply chain, ciclo di vita, benessere umano).
- **WP3**: Materiali e tecnologie innovative per edifici/infrastrutture.
- **WP4**: Soluzioni digitali, compresa l'architettura software/hardware.

- **WP5**: Strategie di comunicazione e disseminazione (C&D), identità visiva e materiali promozionali.
- **WP6**: Impostazione delle strategie di sfruttamento, innovazione sociale e connessione con progetti europei affini (es. Built4People).

Risultati attesi: definizione delle basi concettuali e progettuali per strumenti e soluzioni da sviluppare nelle fasi successive.

FASE 2 – *Develop* and *Test* (Mese 13-30, WP7–WP13)

Obiettivo: Sviluppare concretamente strumenti e soluzioni, testarli nei siti dimostrativi.

- **WP7**: Sviluppo delle due funzioni del tool CREMA (valutazione resilienza attuale + valutazione impatto interventi).
- **WP8–WP10**: Realizzazione finale del toolkit MULTICLIMACT:
  - WP8: Design;
  - WP9: Definizione di materiali/tecnologie;
  - WP10: Implementazione delle soluzioni digitali;
- **WP11**: Pianificazione e implementazione delle attività dimostrative delle soluzioni sviluppate nei 4 siti pilota.
- **WP12**: Avvio delle strategie di comunicazione, disseminazione, pubblicazioni scientifiche e partecipazione a eventi.
- **WP13**: Gestione della proprietà intellettuale, modellazione di business, cooperazione internazionale.

Risultati attesi: test sul campo, raggiungimento dei livelli di maturità tecnologica (TRL), prime evidenze di efficacia delle soluzioni.

FASE 3 – *Deploy and Revise* (Mese 31-42, WP14–WP17)

Obiettivo: Validare, ottimizzare e diffondere soluzioni; avviare replicabilità e raccomandazioni politiche.

- **WP14**: Ottimizzazione finale dello strumento CREMA sulla base dei feedback dai siti dimostrativi.
- **WP15**: Installazione e valutazione delle soluzioni del toolkit MULTICLIMACT.
- **WP16**: Disseminazione estesa, inclusa promozione su scala UE e internazionale (policy maker, cittadini, professionisti).
- **WP17**: Attività per scalabilità, replicazione e standardizzazione, incluso contributo a raccomandazioni politiche e comitati di normazione.

Risultati attesi: dimostrazione finale delle soluzioni, inserimento sul mercato (es. tramite CIW - Climate Innovation Window), cooperazione internazionale e politiche di resilienza più solide.

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In MULTICLIMACT sarà dimostrato il framework di resilienza, il tool e tutte le soluzioni del toolkit in quattro siti dimostrativi multiscala (dal singolo edificio alla scala territoriale estesa), situati in diverse aree geografiche caratterizzate da differenti rischi climatici e naturali rilevanti a livello locale, e che coprono differenti condizioni umane, sociali ed economiche.

La Figura 1 rappresenta la posizione dei quattro siti dimostrativi, i quali si trovano in tre diverse zone climatiche:

- Europa occidentale e centrale (WCE),
- Europa settentrionale (NEU),
- Area mediterranea (MED).

Queste zone sono caratterizzate da diversi tipi di rischi, che vanno da temperature estreme a inondazioni urbane e territoriali e siccità.

Figura 1: *MULTICLIMACT demonstration sites*

Per l'Area mediterranea è stato selezionato il territorio del Comune di Camerino per quanto riguarda la scala territoriale, mentre l'edificio delle Carmelitane di proprietà dell'Università di Camerino per la scala di singolo edificio. Le principali sfide che si prefiggono risultano essere:

- *Sfida socio-economica:* creare una cultura della consapevolezza del rischio naturale e climatico negli studenti residenti nell'edificio, ma anche tra i cittadini locali. In quest'ottica, sarà fondamentale il ruolo del Comune, così come il coinvolgimento degli studenti residenti nella sperimentazione delle soluzioni digitali MULTICLIMACT. In particolare, saranno promosse iniziative come l'accesso aperto ai dati di monitoraggio strutturale ed energetico e agli indicatori chiave di prestazione (KPI) derivati, con l'obiettivo di aumentare la consapevolezza dei cittadini su queste tematiche, contribuendo così alla creazione di una comunità informata.
- *Sfida per la qualità della vita umana:* la misurazione dei parametri ambientali interni e fisiologici consentirà il calcolo di KPI legati alla salute e al benessere, fornendo indicazioni su come migliorare la resilienza tra persone e edificio. La disponibilità di un'applicazione dedicata per la condivisione diretta dei dati con gli occupanti dell'edificio permetterà loro anche di ricevere allerte precoci in caso di eventi sismici.
- *Sfida della catena di approvvigionamento:* alcuni dei materiali utilizzati per ristrutturare e isolare l'edificio possono essere di origine biologica e forniti da consorzi di agricoltori e attività agricole presenti nell'area di Camerino. Tuttavia, è necessario comprendere quali biomateriali siano disponibili e la fattibilità della relativa catena di approvvigionamento, sotto i profili sociale, economico e ambientale. Inoltre, i rischi legati al clima possono influire sulla robustezza di

queste catene di approvvigionamento, rendendo necessaria una maggiore comprensione e valutazione della loro resilienza.

- *Sfida dell'interoperabilità:* dimostrare l'interoperabilità tra le soluzioni digitali fornendo al Comune la piattaforma ENEA SCP (Smart City Platform) per la raccolta e il monitoraggio di dataset armonizzati prodotti dalle soluzioni digitali (ad esempio i dataset di CIPCast e dello strumento LIS relativi rispettivamente alla scala urbana e a quella edilizia), e abilitando la comunicazione interoperabile tra le soluzioni tramite una piattaforma centrale.

Il sito dimostrativo italiano sperimenterà diversi componenti del toolkit MULTICLIMACT (T11.1 e T15.1), che risulteranno estremamente preziosi in termini di potenziale replicabilità, sia per l'ampia area del territorio italiano soggetta ad alto rischio sismico (così come in altri Paesi con tecniche costruttive simili), sia per gli altri rischi climatici specificamente individuati. In particolare, saranno sviluppate:

Pratiche e metodi di progettazione: interventi di riqualificazione energetica orientati alla resilienza, che contribuiscono alla protezione climatica dell'ambiente costruito su più scale (T8.4); progettazione dell'ambiente costruito centrata sull'uomo per migliorare la salute e il benessere delle persone (T8.5).

Materiali e tecnologie: componenti edilizi a energia quasi zero (EECs) auto-sensibili per il monitoraggio dello stato di salute strutturale generale e dei carichi esterni; malta multifunzionale a basso impatto ambientale per ridurre il fabbisogno energetico degli edifici e migliorare il comfort e la salute degli occupanti (T9.3).

Soluzioni digitali: sistema di supporto alle decisioni per la prevenzione e la stima dei danni causati da eventi naturali estremi su più scale, inclusi edifici e centri storici (T10.1); strumento multiuso per il monitoraggio del comportamento ambientale e strutturale degli edifici, per un approccio integrato alla resilienza uomo-edificio e all'allerta precoce, comprensivo di sensori indossabili per il monitoraggio fisiologico del comfort e della salute degli occupanti (T10.2).

Dimostrazione del framework MULTICLIMACT alla scala dell'edificio (T11.1)

Il task T11.1 è dedicato alla sperimentazione e dimostrazione del framework MULTICLIMACT e delle soluzioni tecnologiche sviluppate, presso il sito dimostrativo italiano. La sperimentazione al livello di singolo edificio comprenderà la sperimentazione di tutte le soluzioni del toolkit MULTICLIMACT sviluppate nei task T8.5, T9.3, T10.2.

Il processo di sperimentazione sarà svolto in stretta collaborazione tra gli stakeholder pubblici/leads del demo, ovvero l'Università di Camerino (UNICAM) e il Comune di Camerino (CAM), insieme ai partner responsabili dello sviluppo delle soluzioni del toolkit da testare nel sito italiano.

Gli obiettivi della sperimentazione nel caso pilota comprendono:

- **Lo sviluppo di un quadro di valutazione completo** per il benessere fisico, mentale e sociale, basato su indicatori chiave di prestazione (KPI) definiti nella fase precedente del progetto. Questo quadro è pensato per essere applicato nel dimostratore italiano e fornisce un approccio strutturato per valutare in che modo le progettazioni dell'ambiente costruito influenzino la salute umana in molteplici

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dimensioni. Esso si basa su KPI predefiniti per garantire coerenza e misurabilità, costituendo la base per le valutazioni successive.

- **La progettazione di un protocollo di studio completo** che incorpori misure di valutazione soggettive e oggettive. Questo protocollo mira a valutare l'efficacia delle soluzioni progettuali implementate, combinando dati soggettivi (ad es. comfort multidimensionale e percezioni degli occupanti) con dati oggettivi (ad es. parametri fisiologici e ambientali), nonché con dati fisiologici individuali (ad es. segnali di attività elettrodermica (EDA) e temperatura cutanea). Questo approccio consente una valutazione olistica degli esiti relativi al benessere.
- **L'elaborazione di un esempio di buona pratica.** Sulla base dei risultati del quadro di valutazione e del protocollo di studio, questo obiettivo si concentra sulla creazione di un esempio di buona pratica che dimostri l'applicazione efficace dei principi del design centrato sulla persona. Tale esempio fungerà da guida pratica per progetti futuri, illustrando strategie efficaci per migliorare salute e benessere in contesti simili.
- **Di confrontare** attraverso le misurazioni ambientali e fisiologiche il benessere delle persone all'interno degli ambienti (T10.2) nei quali sono stati implementati differenti interventi di riqualificazione energetica (impiego di soluzioni tradizionali o soluzioni naturali sviluppati all'interno del T9.3 del progetto).

Gli occupanti dell'edificio Carmelitane saranno direttamente coinvolti nella sperimentazione delle soluzioni MULTICLIMACT, attraverso l'utilizzo del protocollo (T8.5) e del sistema di monitoraggio (T10.2) elaborati per valutare il comfort termico e il benessere degli occupanti. A tal fine, saranno utilizzate analisi avanzate dei dati e una rete distribuita di sensori, che verranno installati con l'obiettivo di aumentare la consapevolezza degli utenti riguardo allo stato di salute strutturale, al comfort termico e all'efficienza energetica, oltre a generare allerte precoci, migliorando così la resilienza dell'edificio e degli individui.

I dati acquisiti dal sistema di monitoraggio ambientale e personale saranno gestiti in tempo reale dalla piattaforma LIS, la quale sarà connessa con i dati dei sensori provenienti dall'infrastruttura IoT. Sulla base dei dati reali, la piattaforma sarà in grado di analizzare e confrontare scenari futuri e modelli matematici teorici sviluppati dai partner, relativi a indicatori di efficienza energetica, qualità ambientale interna, salute e benessere degli occupanti, e stato di salute strutturale in caso di sisma. I sensori saranno selezionati tenendo conto del loro posizionamento ottimale e dei metodi di analisi dei dati in relazione alle sollecitazioni ambientali. Verranno considerati diversi approcci, dai metodi basati sui dati ai modelli aggiornati. Sarà inoltre sviluppata una piattaforma di analisi dei dati come archivio pubblico accessibile a tutti i partner, in modo che i dati possano essere recuperati e processati da ciascuno. I dati saranno analizzati automaticamente e raggruppati utilizzando l'algoritmo di clustering k-means.

I partecipanti saranno esposti a diverse condizioni termiche tipiche delle stagioni dell'anno. Verrà chiesto loro di compilare questionari riguardanti la loro percezione termica, il comfort e il loro stato emotivo, mentre verranno acquisiti i loro segnali fisiologici (ad esempio, segnale fotopletismografico, segnale elettrocardiografico, saturazione di ossigeno nel sangue,

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temperatura della pelle, ecc.). I dati saranno analizzati in correlazione con i parametri ambientali rilevati. Questi risultati sono potenzialmente rilevanti sia per l'ottimizzazione del benessere che per il miglioramento della produttività nell'ambiente costruito, oltre che per il miglioramento del consumo energetico degli edifici.

L'analisi avanzata dei dati sarà utilizzata per finalità di classificazione e previsione in termini di sensazione termica, nonché per l'ottimizzazione del funzionamento degli impianti HVAC, con conseguente riduzione dei consumi energetici dell'edificio e miglioramento della qualità della vita indoor e del benessere generale degli occupanti.

I test saranno eseguiti nelle due stanze selezionate presso l'edificio Carmelitane. Entrambe le stanze (stanza 1 e 2) si trovano al primo piano dello stabile e sono completamente accessibili. La stanza 1 sarà allestita con una configurazione "standard", utilizzando interventi di riqualificazione energetica basati su pannelli isolanti di origine petrolchimica, come il polistirene espanso (EPS) e il polistirene estruso (XPS), comunemente impiegati nei tradizionali interventi edilizi. La stanza 2, invece, sarà dotata di un allestimento che prevede l'impiego di materiali/prodotti innovativi di origine naturale e locale, come pannelli in fibra di canapa, anch'essi disponibili sul mercato. In aggiunta, in una parete della stanza 2 sarà applicata una malta multifunzionale sviluppata nei T3.3 e T9.3 del progetto e destinata al miglioramento della qualità dell'aria interna (IAQ – Indoor Air Quality) e della qualità della vita (QoL – Quality of Life) degli occupanti, oltre che dei sistemi basati su materiali self-sensing per il monitoraggio strutturale e sismico.

Selezione dei partecipanti

Per la sperimentazione si prevede il reclutamento di 30 soggetti volontari (età ≥18 anni), facenti parte della comunità dell'Università di Camerino (Docenti, Ricercatori, Studenti, Personale Amministrativo, ecc..) ed i soggetti coinvolti nel progetto di ricerca MULTICLIMACT. Anche se il numero di partecipanti coinvolti possa sembrare non molto esteso, tuttavia può essere considerato sufficiente per validare la metodologia proposta per il caso pilota in condizioni reali.

Procedure Sperimentali

La procedura prevede (vedi allegato Test_protocol_MULTICLIMACT_DEF.pdf) una sessione di test della durata di circa 90 minuti, durante la quale il partecipante può svolgere liberamente attività di sua scelta, come leggere o lavorare al computer, proprio come farebbe in una normale giornata lavorativa. L'obiettivo è osservare il comportamento e il comfort del soggetto in condizioni quotidiane, senza modificare intenzionalmente l'ambiente circostante. La sessione viene ripetuta in entrambe le stanze selezionate (stanza 1 e 2) che prevedono l'implementazione delle due differenti soluzioni.

Durante il test, ogni 15 minuti a partire dal quindicesimo minuto iniziale, viene somministrato un questionario per registrare l'attività svolta e raccogliere informazioni sul comfort percepito. I questionari, basati sulle scale ASHRAE, utilizzano una valutazione a 5 punti per misurare la sensazione, la preferenza, la soddisfazione e lo stato affettivo legati a più

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domini ambientali. I dati raccolti consentono di calcolare indici di percezione e comfort multidominio.

Nel corso del test, ai partecipanti è richiesto di portare con sé il proprio laptop o un libro. Sono inoltre consentite le normali operazioni di ventilazione (come l'apertura delle finestre) e l'utilizzo di dispositivi personali per il comfort, come ventilatori o stufette, in base alla stagione.

Oltre alla valutazione sulla esperienza soggettiva degli occupanti tramite la somministrazione dei questionari (vedi allegato MULTICLIMACT_Survey_DEF.pdf), saranno effettuate delle misure sulle condizioni ambientali e fisiologiche dei soggetti partecipanti utilizzando sensori fisiologici indossabili (acquisizione del segnale fotopletismografico – PPG –, attività elettrodermica – EDA –, temperatura cutanea e segnali relativi al movimento).

I sistemi e le metodologie di acquisizione includono:

- **Emotibit [1]**, un sensore indossabile multidominio (smartband) in grado di raccogliere segnali EDA, temperatura cutanea, segnale PPG, umidità e temperatura, nonché segnali relativi al movimento (attraverso giroscopio, accelerometro e magnetometro).
- **Sensore DomX** (DomX IoT technologies, Salonicco, Grecia), un sistema di misurazione ambientale multidominio che include sensori per la valutazione della qualità dell'aria interna: temperatura (°C), umidità relativa (%), pressione atmosferica (Pa), PM1, PM2.5 e PM10 (μg/m^3), CO_2 (ppm), VOC respiratori (ppm) e illuminamento (lux).
- **Questionari** su informazioni demografiche e personali, comfort multidominio, affettività positiva e negativa (PANAS) e livello di abbigliamento.

I sensori indossabili verranno indossati sul polso non dominante dei partecipanti. I sensori ambientali saranno posizionati in un punto unico nella stanza (ad esempio su una scrivania). Inoltre, per valutare l'effetto di un pannello isolante a base di malta multifunzionale (brevettata da UNIVPM) volto a migliorare la qualità dell'aria interna (IAQ)

L'intero test viene eseguito tramite la piattaforma LIS, grazie alla sua precedente implementazione nel sistema digitale, che consente non solo la somministrazione dei questionari, ma anche la raccolta e la sincronizzazione dei dati provenienti da sensori differenti, in scenari multi-occupante (fino a 4 soggetti monitorati contemporaneamente).

Analisi dei dati

I dati acquisiti saranno elaborati sia con algoritmi integrati nella piattaforma di acquisizione sia con altri sviluppati in ambiente MATLAB/Python. L'obiettivo dell'elaborazione è correlare le quantità fisiologiche con i parametri ambientali e con i risultati dei questionari, al fine di sintetizzare indici relativi al benessere e alla salute dei soggetti. Inoltre, tecniche di Intelligenza Artificiale e Apprendimento Automatico, così come modelli termo-fisiologici esistenti, potranno essere applicati anche per finalità predittive su diverse variabili, sia ambientali (ad es. temperatura e umidità relativa), sia soggettive (ad es. frequenza cardiaca o indici di salute/benessere). Queste informazioni potranno essere utilizzate per il controllo termo-igrometrico dell'ambiente costruito, con l'obiettivo di

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ottimizzare sia il benessere degli occupanti che il consumo energetico dell'edificio. Inoltre, gli indici di salute e benessere verranno integrati nel modello BIM dell'edificio.

Benefici dei partecipanti alla ricerca

Attraverso l'analisi approfondita ed avanzata dei dati acquisiti dal sistema di monitoraggio, sarà possibile effettuare la classificazione e la previsione della sensazione termica percepita dagli occupanti, nonché ottimizzare il funzionamento degli impianti di climatizzazione HVAC (Heating, Ventilation and Air Conditioning). Questo consentirà una riduzione dei consumi energetici dell'edificio e un miglioramento della qualità della vita indoor e del benessere generale degli utenti.

Responsabilità dei partecipanti alla ricerca

Ogni partecipante alla presente ricerca è responsabile di:

Integrità dei dati forniti: Fornire risposte accurate e sincere ai quesiti, assicurandosi di comprendere le domande e di dare risposte pertinenti.

Diritto di rifiuto: Rifiutare di partecipare alla ricerca o di rispondere a specifiche domande senza dover fornire una motivazione.

Comunicazione: Comunicare al ricercatore qualsiasi dubbio o apprensione riguardo alla ricerca.

Rischi

Nella sperimentazione non vi sono problemi di sicurezza in relazione ai test, in quanto i partecipanti non saranno esposti a condizioni diverse dalle loro normali condizioni di lavoro.

Obbligo di riservatezza

Nessuna informazione identificativa sarà inserita nei moduli compilati. I dati acquisiti saranno gestiti dai responsabili della piattaforma in accordo con quanto previsto dalla legge sulla privacy (Legge n. 675 del 31 dicembre 1996). Per garantire una maggiore tutela saranno adottate le seguenti misure:

- Assegnazione di codici o numeri identificativi anonimi ai partecipanti, che saranno utilizzati per l'intera durata dello studio.
- Nessuna conservazione di appunti, trascrizioni di interviste o altre informazioni che possano identificare il partecipante.

I dati dei partecipanti saranno mantenuti riservati, salvo nei casi in cui il gestore dell'archivio sia legalmente obbligato a segnalare determinati eventi che violino le leggi vigenti.

Disseminazione e pubblicazione dei risultati dello studio

I dati acquisiti durante la sperimentazione saranno rielaborati all'interno del progetto di ricerca MULTICIMACT ed i risultati della sperimentazione saranno riportati all'interno dei Deliverable specifici di rendicontazione del progetto stesso.

In accordo con quanto previsto dal progetto, i dati e/o altri risultati della ricerca generati dal progetto MULTICLIMACT saranno gestiti in linea con i principi FAIR:

(1) Rintracciabilità (Findable): il consorzio pubblicherà apertamente codici, liste di codici e metadati su una piattaforma GitHub, promuovendoli attraverso il sito web del progetto e le pubblicazioni scientifiche. Per

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facilitare la reperibilità dei dataset, essi saranno nominati seguendo una logica univoca: *MULTICLIMACT.CodicePaese.NomeDataset.Versione*.

(2) Accessibilità (Accessible): il consorzio si impegnerà a rendere i dati e gli altri risultati della ricerca il più aperti possibile, o accessibili tramite servizi open, tenendo comunque conto degli obblighi generali di riservatezza previsti dall'Articolo 21 e delle norme sui dati personali ai sensi dell'Articolo 23 del Grant Agreement UE. I deliverable contrassegnati come pubblici saranno resi disponibili attraverso il sito web del progetto e piattaforme correlate come Zenodo, OpenAIRE, in conformità con il Grant Agreement e il Consortium Agreement. Nei deliverable pubblici, tutti i dati saranno anonimizzati.

(3) Interoperabilità (Interoperable): saranno adottate misure per garantire che le attività rispettino standard riconosciuti, utilizzando formati standardizzati per variabili, codici, liste di codici e metadati, al fine di massimizzare la riproducibilità internazionale dei risultati. Le linee guida seguite includeranno: formati non proprietari e non legati a software specifici; standard aperti e documentati; formati comuni utilizzati dalla comunità scientifica; rappresentazione standard (Unicode, ASCII); dati non crittografati e non compressi.

(4) Riutilizzabilità (Reusable): laddove possibile, i dati della ricerca saranno concessi con licenza open access. Tuttavia, ciò dipenderà dalla natura e dal livello di privacy, nonché dai diritti di proprietà intellettuale (IPR) associati ai dataset. Questo principio sarà garantito attraverso la pubblicazione su piattaforme come Zenodo. I limiti temporali per il riutilizzo dei dati saranno allineati agli standard della piattaforma Zenodo. Durante il progetto, man mano che i dati saranno identificati e raccolti, le informazioni saranno aggiornate nelle diverse versioni del Data Management Plan (D6.3, D13.2, D17.2).

Il consorzio ha individuato i seguenti dataset rilevanti che potrebbero essere elaborati durante il progetto:

(1) Dati di ricerca / Risultati:

- Questionari;
- Output (dati grezzi) delle attività di innovazione sociale e dell'uso dell'app mobile, sondaggi e interviste (WP1, WP4, WP5, WP7, WP8, WP9, WP10, WP11, WP12, WP14, WP15, WP16);
- Risultati di misurazioni e osservazioni (WP3, WP8, WP9, WP10, WP11, WP15);
- Dati per la caratterizzazione dei casi studio (WP8, WP9, WP10, WP11, WP15), inclusi dataset o fonti preesistenti;
- Immagini, registrazioni audio e video.

(2) Dati personali:

- Dati personali dei partecipanti ad attività di co-creazione e co-sviluppo rilevanti, come nome, età, contatti (non applicato ai soggetti partecipanti alla sperimentazione);
- Dati degli iscritti alla newsletter e dei follower dei profili social (WP5, WP12, WP16) (non applicato ai soggetti partecipanti alla sperimentazioni).

(3) Dati per la valutazione:

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- Dati di valutazione del coinvolgimento degli stakeholder, derivanti dall'interazione degli utenti con lo strumento CREMA (WP7, WP11, WP14, WP15).

MULTICLIMACT si atterrà a tutti gli standard etici pertinenti, alle linee guida di Horizon Europe e alla legislazione nazionale ed europea vigente. I partner possiedono conoscenze e esperienza di conformità ai requisiti etici e legali della Commissione Europea per i progetti finanziati dall'UE. Un comitato etico è incluso nella struttura di gestione del progetto (WP, WP13, WP17).

Ritiro dallo studio

Il soggetto può scegliere di abbandonare la sperimentazione in qualsiasi momento. Se sceglie di partecipare allo studio, è necessario firmare un modulo di consenso informato. Dopo aver firmato il modulo di consenso informato, il partecipante può comunque abbandonare lo studio in qualsiasi momento, senza alcun pregiudizio e senza alcuna giustificazione. In tal caso, tutti i dati relativi ai partecipanti saranno distrutti; la scelta non influirà in alcun modo sul rapporto con il ricercatore.

Compenso per i partecipanti

Non è previsto nessun compenso ai partecipanti alla sperimentazione, in quanto è su base volontaria.

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[2] European Commission, 2021: *Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions. Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change*. Brussels, 24.2.2021 COM (2021) 82.

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[4] https://cdn.cdp.net/cdp-production/cms/reports/documents/000/006/567/original/CDP_Cities_Protecting_People_and_the_Planet.pdf?1665068434

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