Chapter 8
Advancing the Design Process Experience of Heritage Buildings' Renovation: A Toolkit for an Ethical Best Path

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Abstract The paper focuses on the innovation and sustainability of energy renovations for public buildings in the Mediterranean area by means of more inclusive and digital processes. Aligning with the most ambitious directions of the European Green Deal and collaterals in the sector, the research object of this contribution consented to experiment strategies for engaging people in building energy renovation processes, tested in the development of a real-case pilot through Living Lab and digital twin methodologies. With the aim to stimulate an ethical evolution in renovation praxes and outcomes for public buildings retrofit, the contribution shares the methodology, the structure and the main contents of the project's research output (Toolkit) guiding step by step more inclusive processes for a green and digital but also social transition.

Keywords Building renovation · BIM · Digital twin · Living Lab · Participation

8.1 Innovating Building Renovation

8.1.1 Background: EU Directions

Despite the 20-year-old Energy Performance Building Directive (EPBD 2002, recast in 2010, amendment in 2018 and new amendments in 2023), still 75% of the EU building stock remains inefficient with low renovation rates. Considering that in

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the European Union buildings are responsible for roughly 40% of energy use and 36% of energy-related greenhouse gas emissions, making them the largest energy consumers, and that this is the global trend, the acceleration of renovations represents a huge challenge and a top priority. Over the course of EPBD evolution, a progressive attention has been posed on the rehabilitation of existing buildings, with even deeper renovations required to reach zero-energy targets.

In the context of the ambitious European Green Deal aiming to cut 55% of greenhouse emissions by 2030 and to reach climate neutrality by 2050, addressed in the 2021 "Fit for 55" legislative package, the EU Commission launched the Renovation Wave strategy (2020) to set out how to achieve a zero emission and fully decarbonised building stock. The strategy emphasises the principle of "energy efficiency first", the objectives of decarbonisation and integration of renewables, life cycle thinking and circularity, high health and environmental standards, also considering architectural quality and aesthetics. The strategy also expresses the need, and opportunity, to tackle together the twin challenges of the green and digital transition, promoting digitally friendly renovations.

The most meaningful approach regards the objective of taking the maximum contribution of energy rehabilitations, not only in terms of energy savings and environmental impacts (reduction of energy consumption and of greenhouse emissions) but also considering the wider benefits related to health and comfort for occupants, improved living conditions and promotion of sustainable lifestyles. This approach aligns with the New European Bauhaus (NEB) initiative, which fosters creativity and transdisciplinarity in designing sustainable living spaces, which can be inclusive and beautiful, emphasising the role of local communities.

Both the strategies (Renovation Wave and NEB) and their approaches have been recalled in the new EPBD recast, approved after a long debate in March 2023.

Addressing the compelling energy problems exacerbated by the recent geopolitical involution, the recast reinforces the minimum energy performance standards (public not residential buildings are required to reach the energy class E within 2027 and D within 2030), with a decisive focus on the production of local clean energy (i.e. solar energy) to phase out fossil fuel use in buildings. At the same time, the recast also highlights the need to consider the whole-life cycle reduction of carbon emissions (i.e. circular and natural materials), introducing the GWP (Global Warming Potential), indicating over the whole life cycle the building's overall contribution to emissions that lead to climate change.

Introduced amendments include new stimulating approaches related to the adoption of "simple passive low-tech and locally tested building techniques", the integration of "green infrastructures" and "nature-based solutions" (enlarged to the district level to contrast summer heat waves and sustaining biodiversity), such as a renewed attention to indoor environmental quality and benefits in terms of social wellbeing.

Moreover, in the wake of the digital transition, a growing consideration has been posed on the contribution of "3d based modelling and simulation technologies" (referring to BIM), whose management, visualisation and predictive capabilities can play an enabling role in collaborative processes, consenting to establish a "multi-level dialogue" between a wide range of stakeholders.

8.1.2 New Approaches to Renovation

All buildings have a potential to be renovated for enhanced energy efficiency, eco-compatibility, improved comfort for occupants and architectural quality: untapping this multi-objective improvement potential can be considered as an ethical objective (Gemanà 2021).

Stimulated by financial bonus, the investment on building renovations is activated when a return of capital is guaranteed in terms of energy savings, considering the main indicator of energy consumptions. This approach results in the isolated work of technicians called to find the most suitable solution to match energy efficiency with savings, usually limited to invisible interventions on plant systems, impeding the take into account the integrated dimension of renovations.

When the multiple dimensions of the renovation potential is acknowledged, recognised and shared, the possibility of economic investments can be stimulated and expanded, and more innovative outcomes can be produced. Beyond the economical return, renovations can be improved by re-valuing the role of architecture, traditional passive solutions, integration of natural elements and, above all, people, in terms of comfort, wellbeing (Battisti 2023) and proactive behaviours (Delera and Lucchi 2020).

This ambition appears particularly important when referring to public buildings, for their exemplary role recognised by EU directives but also for the ethical responsibility of public bodies in guaranteeing quality spaces and sustainability.

To overcome the weak implementation and fragmentation of retrofit processes in Mediterranean public buildings and to boost the renovation path, public administrations and management bodies have to be ready not only to take advantage of digitalisation but to open the processes towards a renewed green sensibility and to the local community of stakeholders and users.

New stimulating instances, such as the introduction of beauty, nature and human comfort in traditionally hard technology processes as retrofits, but also the adoption of soft technologies as BIM methodologies, represent a call to all the renovation actors to update working and procedural praxes. For this purpose, universities can play the catalytic role of testing innovation and providing tools and instruments to support the public sector in a smooth transition towards the future.

8.2 The Toolkit for Innovative and Eco-sustainable Renovation Process

8.2.1 Background: The Med-EcoSuRe Project

The “Toolkit for Innovative and Eco-Sustainable Renovation Processes” is an output of the Med-EcoSuRe project-Mediterranean University as Catalyst of Eco-Sustainable Renovation, financed by the ENI CBC MED Basin Programme 2016–2020 (https://www.enicbcmed.eu/projects/med-ecosure). Addressing the renovation challenge, the project aimed at generating and implementing innovative and eco-sustainable energy renovations in Mediterranean higher-education institutions, as “testing rooms” to stimulate the wider renovation of public buildings.

Fixing the principle that working together with stakeholders and users in participatory processes can produce more sustainable and innovative solutions, the project considered collaboration as the key to overcoming the current bureaucratic, regulatory and planning issues, such as institutional and structural bottlenecks, slowing and limiting renovations.

To accelerate the implementation of public buildings renovation in the Mediterranean region, the project supported the activation of university-based Living Labs (LL), as real-life laboratories where the university community, as a little society, can co-experiment, test and share innovative renovation processes, strategies and technologies (Trombadore and Calcagno 2022a).

For their innate nature of education, research and technological transfer, universities are in fact the ideal place for delivering innovation through LL approaches, consenting to capitalise the state of art of academic knowledge and to exploit the know-how of the local network of stakeholders (innovative companies, public administrations), eventually allowing the young generation of students to take part in real-life renovation process and increase their awareness of sustainability issues (Fig. 8.1).

Project’s outcomes draw from the two main levels explored through the LL approach. At Mediterranean level, an intense exchange of experiences occurred within the Med-EcoSuRe initialised cross-border Living Lab, “Med beXLive”, connecting an excellence network of experts in the field of renovation of Mediterranean public buildings. At the local level, the activation of a Living Lab in the School of Architecture of the University of Florence (Italy), working on the real case of the pilot renovation action (Fig. 8.2), led to establishment of an interdepartmental laboratory integrating three departments of architecture, energy engineering and information engineering, oriented to the experimentation of digital twins (Trombadore et al. 2020).

The experience of the local Living Lab has been capitalised in the “Toolkit for Innovative and Eco-Sustainable Renovation Processes” (Toolkit), whose objectives, structure and main contents are presented in this contribution (Fig. 8.3).

Fig. 8.1 The project targets five main audience groups involved in the renovation process of the university building: students, companies, building/energy managers, public organisations and researchers

Fig. 8.2 Med-EcoSure's pilot project in the School of Architecture of the University of Florence

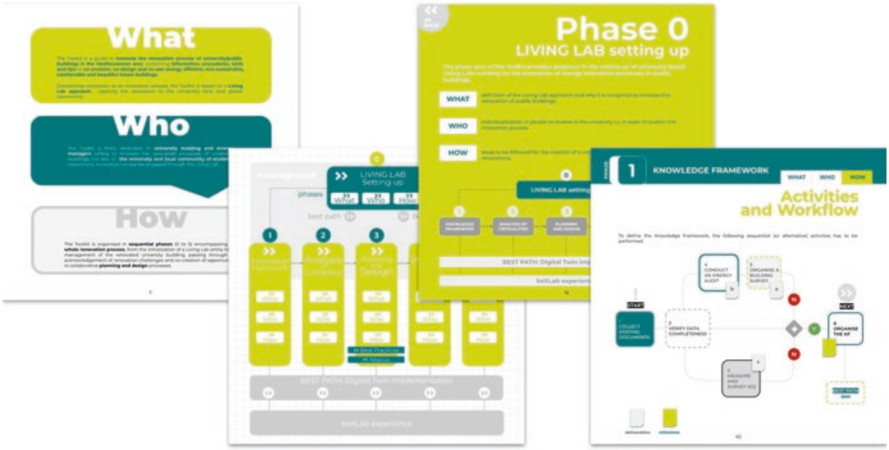

Fig. 8.3 An example of the Toolkit pages

Firstly dedicated to public building and energy managers, the Toolkit has been intended to stimulate more inclusive and collaborative approaches in renovation processes, containing information, procedures, tools and tips to co-envision, design and use energy-efficient, eco-sustainable, comfortable and beautiful future buildings. As an easy-to-use guide, the Toolkit supports the implementation of LL methodologies to explore novel forms of collaboration among decision-makers, stakeholders and end-users for the planning and execution of sustainable renovation initiatives, focusing on the opportunities of digitalisation in supporting such more inclusive approaches.

8.2.2 The Renovation Objectives in the Toolkit

The need to look beyond energy efficiency suggested by the EU directions can be addressed in co-design processes, the heart of the Living Lab approach, exploiting the design culture and creativity for the definition of more ambitious renovation scenarios valorising the role, needs and contribution of people in achieving more ambitious objectives.

Four overarching renovation objectives (Fig. 8.4) have been defined in the Toolkit, guiding and encompassing the whole renovation process:

1. Reduction of energy needs. Renovations strive at first instance to reduce the building's energy needs, so that the low energy demand can be fully satisfied by renewable energy.

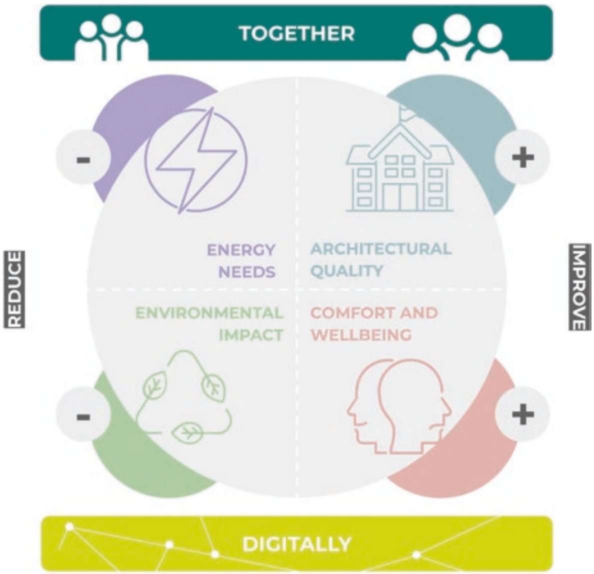

Fig. 8.4 A scheme of the four pillars of the renovation and the two transversal approaches that implement the process

2. Improvement of architectural quality. Renovations are the occasion for an aesthetical requalification of existing buildings, with architectural quality contributing to the definition of a new image speaking of sustainability.
3. Improvement of comfort and wellbeing. Renovations improve the Indoor Environmental Quality (IEQ) of existing living spaces, contributing to occupants' comfort, wellbeing and health.
4. Reduction of environmental impact. Ambitious renovations minimise the carbon footprint of buildings and reduce the environmental impacts of existing buildings, starting from the integration of renewable resources towards the adoption of circular and natural materials.

Transversal to the renovation objectives, and more related to people than to buildings, two interrelated approaches can support more collaborative, inclusive and innovative processes, fundamentals to address the complexity of contemporary renovation challenges:

(a) Boosting the proactive role/behaviour of people. Promotion of more collaborative approaches between renovation stakeholders and engagement of end users, in co-design/"aware use" of sustainable university/public buildings, as the best approach.
(b) Untapping the digital potential. Adoption of digital technologies (from BIM to digital twins) to sustain more collaborative and reliable renovation processes, as the best path.

8.2.3 The Toolkit Structure

The Toolkit has been designed as a comprehensive path to explain, step by step, how to approach the retrofit of university/public buildings as an innovative process built around the role of people (decision makers, stakeholders and users), providing with an organised set of methodologies and tools aligned with the EU directions (green and digital transitions) and tailored for the Mediterranean socio-climatic and cultural context.

The renovation process has been divided into five main phases (knowledge framework, analysis of criticalities, planning and design, intervention and post-management), introduced by a phase zero on the setting up of Living Labs (Fig. 8.5).

For each phase, the Toolkit identifies:

– Activities to be undertaken (Fig. 8.6)
– People engaged
– Methodologies and tools for implementation

Moreover, two sessions run parallel to the progression of the renovation phases: the Digital Twin Best Path, on the digital possibilities to innovate the renovation process, and the beXLab Experience, on the Toolkit application in the real-case pilot renovation action in the School of Architecture of the University of Florence.

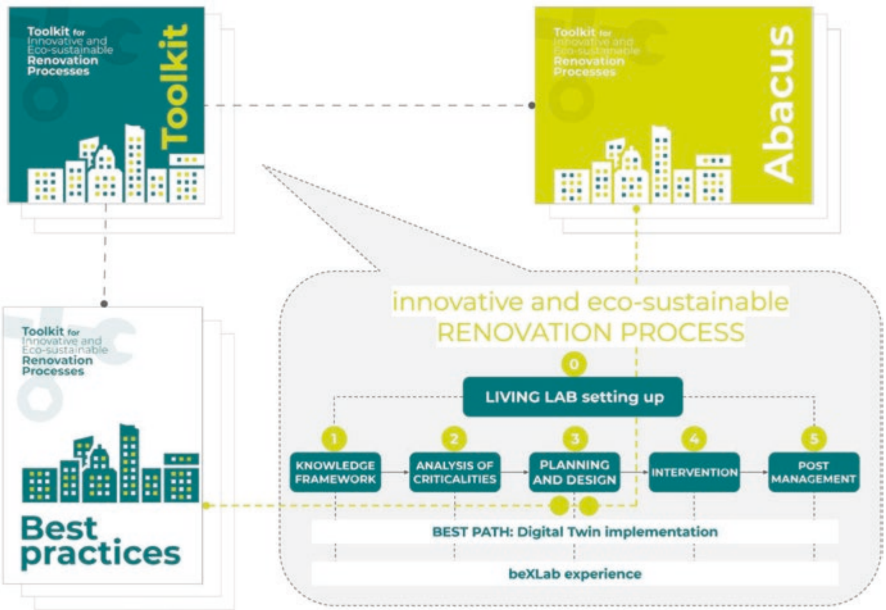

Fig. 8.5 The "Toolkit for Innovative and Eco-sustainable Renovation Processes" is a box composed of three main interactive documents: the Toolkit, the Abacus of renovation strategies and technologies and the Best Practices. The grey part describes the structure of the Toolkit

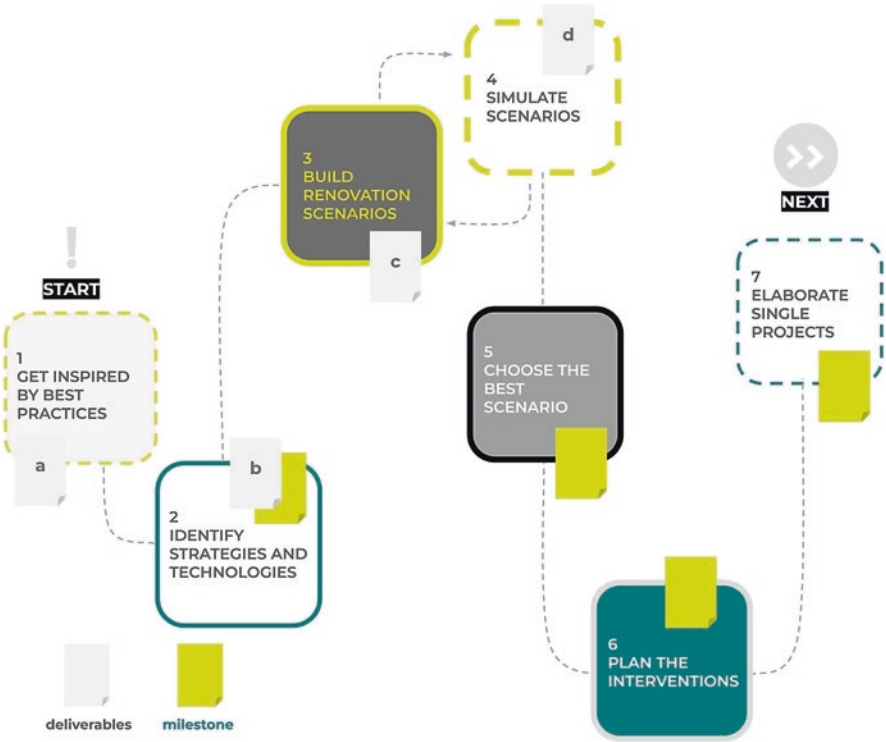

Fig. 8.6 Activities and workflow related to the planning and design phase

The central renovation phase of "planning and design" has been enriched with two additional resources focusing on building-related aspects:

– A best-practices catalogue of recently renovated and newly constructed high educational buildings selected for adopting energy-efficiency solutions.
– An Abacus of retrofit solutions, guiding the selection of the most appropriate renovation strategies, technologies and materials for the Mediterranean socio-climatic and cultural context (Fig. 8.7).

Phase zero is dedicated to the activation of university LLs for the implementation of pilot renovations, containing the methodology and activities for their initialisation, setting up and maintenance. Beyond the general LL activities, key activities are related to the definition of renovation targets: all actors involved in the renovation process have to know which are the most ambitious objectives to address, to define in a clear way in order to make them verifiable across the renovation process.

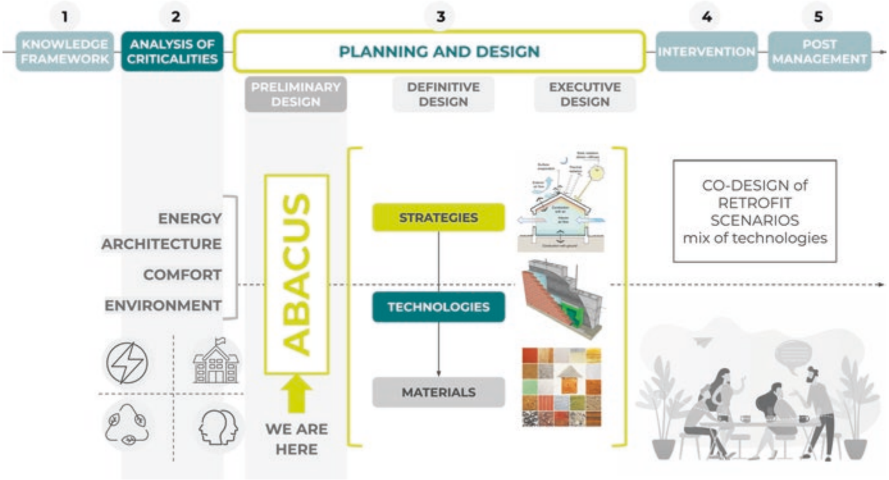

Fig. 8.7 The Abacus is a supporting tool to guide the selection of the best retrofit strategies, technologies and materials during the preliminary design phase

8.3 A Step-by-Step Renovation Process

8.3.1 Phase 1: Knowledge Framework

Precondition for a successful renovation process is the definition of a robust and complete knowledge framework (KF). As an "ID card" of the existing building, KF is an organised collection of data and information describing the real conditions of the building to renovate in relation to the four identified renovation objectives. Retrieved data are relevant to analyse criticalities in the following phase and starting point to evaluate improvement scenarios.

Starting from this first phase, working in the university LL environment can be highly proficuous. Interdisciplinary group of researchers, specialised in renovation-related disciplines, can work together with building/energy managers to find the best ways to overcome the limits/barriers of the current approach to data storage and management. According to the dimension and typology of the pilot building to renovate, but also considering the building park of reference, researchers can suggest the adoption of the state of the art of digital technologies, starting from BIM. As the best path, BIM models can be created to store the collected data in a central repository and to maintain an implementable KF of the building across its whole life cycle: the digital transition can benefit by the tutoring of researchers and experts transferring know-how to the building/energy managers.

The construction of the KF can be critical because of the missing and fragmentation of existing data, requiring in most of the cases the organisation of survey campaigns. In the context of university LLs, students can be involved in fieldwork activities according to their specific disciplines, contributing to the retrieval of missing information as an occasion of learning by doing.

More advanced experimentations in the LL can be created in collaboration with companies of innovative technologies supporting the retrieval of architectural data (e.g. building survey instruments and software), energy data (e.g. energy auditors, ESCOS) and indoor environmental quality data (e.g. sensors and monitoring systems) with innovative methodologies and tools to introduce to managers as well as to students. Also public entities can be engaged in the LL for the definition of the KF, such as public administrations (e.g. municipalities) or, in the case of heritage buildings, public offices for the management of the local architectural heritage: their early involvement can also be profitable to set a smooth authorisation process.

For a more comprehensive acknowledgement of the existing building, dynamic and real-time data on energy performance and indoor environmental quality could be retrieved by the introduction of smart monitoring systems. That was the path followed by the local LL in Florence, where a dense grid of signals coming from tens of installed sensors/IoTs devices and subjective information from surveys are integrated with the BIM model in an ICT platform (Ridolfi 2019). The ambitious digital twin best path consents an augmented experience of the lived spaces, with dynamic and real-time data allowing new connections and new dimensions of awareness.

8.3.2 Phase 2: Analysis of Criticalities

The Analysis of Criticalities (AC) is a comprehensive evaluation of the building, with criticalities assessed in a range that spans from the verification of minimal requirements by law to the gap with the most ambitious renovation targets collectively defined in phase zero.

To create a continuous and easy-to-follow path, also criticalities have been referred to the four individualised renovation objectives: in particular, the AC is the moment when integrated analyses can show the interconnections and dependencies of the interrelated aspects of energy efficiency, indoor comfort, architectural quality and environmental impact.

An initial assessment of methodologies and tools in use to evaluate the criticalities of the university/public building stock can be performed by researchers, who can suggest an updating of analysis practices based on the most recent technological advancements.

Exploiting the LL and the contribution of its participants, the AC can deepen the understanding of the existing building: the interdisciplinary group of researchers can support building/energy managers in the adoption of innovative simulation tools, with the involvement of software house companies and local experts for the activation of training and coaching activities; students and the whole university community can be engaged in survey activities focusing on the perception of the environmental quality inside spaces. Moreover, the renewed attention to human comfort and to environmental issues could be supported by the contribution of dedicated public organisations, enriching the discourse with scientific data to inform the following design phase.

As for KF, the AC can highly benefit from digitalisation: the definition of BIM models of the existing assets (equipped with the data listed in the KF) can be exploited to run simulations on the energy and environmental behaviours of the building (e.g. by leveraging the BIM interoperability with dedicated software, plugins and tools for the analysis of energy, thermal, lighting and acoustic performance). In this phase, simulations serve to enhance the analysis and as a reference, useful to compare with the data coming from the real world, such as energy consumption bills and retrieved data on indoor environmental conditions (e.g. spot monitoring, real-time system, survey answers). The guided visualisation and sharing of data-driven analyses in the LL environment, along with their correlation to monitored and actual data, can facilitate more informed, transparent and shareable decision-making in the subsequent phase.

8.3.3 Planning and Design

The central phase of Planning and Design (PD) is the most beneficial of the LL approach, as this allows for the activation of co-design processes to determine the best renovation scenario, involving stakeholders and end-users in the decision-making.

PD activities are oriented to find the best mix of technologies to integrate in the existing building, to solve the identified criticalities and achieve the established renovation targets.

The BIM asset model, defined in the KF and synchronised with performance simulations tools during the AC phase, can act interactively and iteratively as a benchmark to evaluate the improvements resulting from the integration of individual or set of retrofit technologies across various scenarios, which are compared to the defined baseline.

Beyond the BIM-enabled possibility to optimise the pre-design, thanks to the interoperability with performance simulation tools, working around a single-shared model promotes the collaboration between designers and specialists, as well as the communication with non-experts, such as owners and end-users, facilitating co-design processes. It has to be noted that building energy and environmental performance are usually conducted in later stages of the design process, and primarily for specialistic verification purposes. However, with the use of digital and interoperable models (BIM) and the adoption of simulation approaches during the AC phase, simulations can be anticipated in the first steps of the design process, when modifications have significant impact (Trombadore et al. 2023).

Building on the AC phase, strategies and technologies are discussed, integrated and tested in the model to appreciate the degree of solution of the criticalities and approach to targets. The core of the phase is the definition of integrated improvement scenarios and a methodology for selecting the most efficient one.

Renovation scenarios are developed in relation to the degree of satisfaction of the pre-defined renovation targets, which may relate to costs or to the renovation aspect to prioritise. Addictionally, and according to the financial resources available, interventions can be planned in time.

The construction of reliable scenarios in the LL context offers the significant advantage of combining the knowledge of the interdisciplinary research group and the expertise of building/energy managers, as well as the know-how of stakeholders, in particular companies providing technical specifications of the different retrofit technologies and products to integrate. The search for the best scenario can be supported by co-design workshops involving all the renovation actors, including the valuable contribution of students.

8.3.4 Intervention

Once the executive and approved renovation project, output of the planning and design phase, is in place, the renovation process moves to the intervention phase. This phase regards the construction works necessary to integrate the mix of technologies into the existing pilot-building, ultimately delivering the renovated building for the final post-management phase.

Construction companies play a pivotal role in this phase, and their early involvement in the LL environment ensures alignment of objectives and the establishment of sustainable work sites. These sites can even be opened for educational purposes, providing students with an opportunity to learn in a real-world setting.

The digital environment plays a crucial role in maintaining quality standards, thanks to renewed BIM-based practices allowing building managers a better control over the tendering and execution processes. The continuous implementation of the BIM model leads to the definition of the as-built model, which will serve as a valuable resource throughout the future life cycle of the renovated building.

8.3.5 Post-management

The renovation process extends beyond the completion of construction works, as the effectiveness of the renovation must be verified in the newly renovated building. The intervention phase concludes with the handover, allowing for a thorough inspection of the installations. Subsequently, the post-management phase focuses on the future management, operation and utilisation of the renovated building.

Working in the LL context offers advantages even in this final phase, with actors engaged since the beginning of the process empowered with the responsibility for sustainability issues. Their participation in the renovation project ensures their awareness of the integrated technologies and how to utilise them efficiently to minimise the environmental impact during building operation (through training initiatives).

During this stage, the updated BIM asset model serves as a valuable tool for facility management operations, enabling the connection with building management systems (BMS) and automation systems. The involvement of ICT companies and experts contributes technical expertise to update the management practices of building and energy managers.

In the case of experimentation with digital twin, as in the local pilot project, the implementation of monitoring systems can be exploited for the creation of ad hoc customised ICT solutions fitting the specific management needs. These more advanced experimentations could be the occasion to engage the community of end users in an improved phase use of the renovated building. The availability and visualisation of the monitored energy and environmental data could inform end users in the adoption of more sustainable behaviour, with the possibility to adopt serious games and user experience to create engagement with sustainability issues (Trombadore et al. 2023).

8.4 Conclusions

8.4.1 Open Discussions and Future Applications

The renovation of the inefficient public building stock (not only in terms of energy consumptions) is an ethical challenge, calling for more innovative and sustainable approaches to accelerate and qualify both the processes and the renovation outcomes.

Usually relying on mere technical processes, renovations are mainly developed by technical officers according to the budget availability, evaluating the effects in terms of economic benefit and investment return (payback period of energy savings).

As suggested by the EU directions, this approach can be overcome by reinforcing the ecological, social and ethical dimensions of renovation processes. This shift can be pivoted on a virtuous cycle involving the role of people and digitalisation.

From a side, the strategic engagement of “not-expert people” in Living Lab is an occasion to re-valuing more sensitive aspects, such as human perception, aesthetics and the adoption of passive and nature-based solutions; from the other side, digitalisation can help not only to quantify their benefits in terms of evidence-based data but to showcase the architectural quality of the integrated scenarios. Collaboration and digitalisation appear as game changers to improve both the working routines and the renovation outcomes. By combining people engagement and the utilisation of digital tools, a more holistic and comprehensive approach to renovation can be achieved, ensuring that ecological, social and ethical considerations are prioritised alongside technical and budgetary aspects. Looking at the global urgency of the energy and environmental problems, the adoption of these innovative approaches for the renovation of the public building stock can be considered a responsible and ethical choice:

1. More informed renovations can be enabled, fostering active citizenship and raising awareness of sustainability within the local community. Moreover, platforms and apps can be developed to encourage environmental consciousness and proactive behaviours (social sustainability).
2. A wide range of data and information can be obtained by the different actors, calculated and quantified (e.g. life-cycle analysis, simulations), driving and supporting the selection of ecological technologies, natural or recycled materials as well as passive and nature-based solutions (environmental sustainability) (Trombadore and Calcagno 2022b).
3. The implementation of digital twins allows a deeper analysis of the existing building and the configuration of renovation scenarios and also the maintenance of building stock during the life cycle, optimising costs and performance (economic sustainability).

The proposed Toolkit serves as an initial endeavour in this direction, explained through a step-by-step guide of activities and a real case example, the importance of collaborative ways of working and the potentialities of the digital transition. This approach appears particularly profitable for public heritage buildings, where the opportunity of renovation highly depends on a robust knowledge framework and a reliable analysis of criticalities, whose results can orient the same appropriateness of the destination of use according to the building vocation.

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