World Conference on
Timber Engineering
Oslo 2023

SCALING UP ENGINEERED TIMBER FOR NEIGHBOURHOOD SCALE DEEP RENOVATION: FINDINGS FROM A STUDY IN COIMBRA, PT

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ABSTRACT: European historic city centres embrace a high percentage of masonry buildings with varying materials and configurations, and successive layers of constructive practices. As "deep energy renovations" are progressively imposed in city centres across Europe, structural uncertainty often justifies interior demolitions and the construction of new buildings behind old facades. This linear approach, unsustainable in its´ economical, environmental, and social dimensions, is currently enforced by market players, but also by environmental financing schemes that exclude circular approaches like maintenance and improvement. Departing from a historical masonry building located in the UNESCO-protected area of Coimbra, Portugal, an engineered timber strengthening strategy is shown to solve more than one problem, and proposed as a scalable low-cost solution for entire neighbourhoods' holistic deep renovations. This paper proposes that the high compatibility and "dry" approaches of timber engineering can be scaled up to favour the mass customization, prefabrication and industrialization needed to deliver improved safety and sustainability with lower economic, environmental, and social costs. Taking part in holistic deep renovations will help the sector to solve some of its own difficulties, and to deliver quicker, less expensive, and more sustainable "2050-aligned" deep renovations of European neighbourhoods; and across the world.

KEYWORDS: historic buildings, deep renovation, seismic renovation, masonry buildings retrofit, experimental test

1 INTRODUCTION

Many European historic buildings and neighbourhoods are in-between gentrification and collapse.

These century-old buildings, versatile in attracting new roles and users, are often classified as "energy hogs" by energy efficiency regulations that either exclude them or impose "improvements" mismatched with their design [1]. Prejudice and lack of knowledge about their thermal and structural behaviour often lead to energy-intensive linear processes of demolition and "wet" construction of new buildings inside old facades, with high upfront costs and eviction of their inhabitants for over one year. This process often ends with unaffordable rents for the original inhabitants, leading to gentrification [2].

On the other hand, historic unreinforced masonry buildings—like the one depicted here—are often the least expensive dwellings of European city centres, housing older age/lower income populations vulnerable to (energy) poverty risks. Low rent values mean insufficient income for their maintenance, worsening traditional skilled labour scarcity and rendering them derelict and unstable. As documented in a video filmed nearby, lack of maintenance leads to instability, and collapse. [3]

This dichotomy between gentrification and collapse is not acceptable in a Europe of diversity and knowledge. The relation between structure, energy, materials, finance, architecture, and city planning was tackled in the SAFESUST workshop on "A roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities", yet the problem is still pending. The cover page image [4], in Figure 1, alerts on the need to guarantee buildings' integrity, and the safety of their users, before "decarbonizing" them.

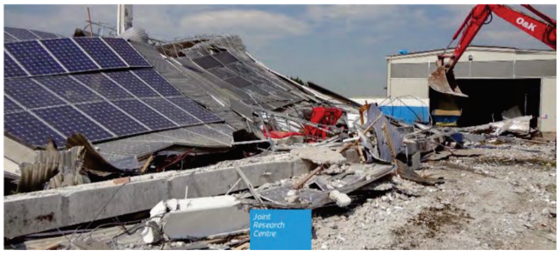

Figure 1: *Cover page depicting a collapsed "decarbonized" building after a seismic event. [4], Source: Telestense TV, Ferrara Italy - from "TV giornale", 2012 May 21st*

Inclusive deep renovations are at the forefront of European concerns, as stated in a recent call: a low-quality building stock impacts its' residents, "*including poorer health and lower levels of social inclusion. Transforming inefficient housing stock addresses a root cause of energy poverty, however, the topic also has as an objective to tackle the related high upfront costs, lack of information and trust, uncertainty about benefits of the measures, split incentives, and discomfort caused by renovation works, including the potential need to relocate, as barriers to household uptake.*" [5].

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https://doi.org/10.52202/069179-0532

This paper proposes that scaling timber-engineered high compatibility and "dry" approaches can deliver quicker, less expensive, and more sustainable deep renovations. Departing from diverse backgrounds and ongoing needs [6] [7] [8] the authors propose engineered timber—a sustainable endogenous material enriched with knowledge—as an emergent solution for 2050 historic neighbourhoods' decarbonization efforts. To bridge the diverse areas this paper aims to engage, this introduction approaches the evolving frameworks and challenges for engineered timber towards the positive and inclusive neighbourhoods needed by 2050, setting the context with academic findings on a historic area under study. Timber in the renovation of existing structures approaches the current (lack of) use of engineered timber, while the discussion questions current legal and constructive practices: scale is needed for holistic views, and to make "deep" diagnosis and design viable before renovation. The conclusion emphasizes the conceptual contradiction of monothematic deep renovations, and the potential of neighbourhood-scale approaches to make interventions more attractive, inexpensive and aligned with 2050 goals.

1.1 ADDED ROLES FOR ENGINEERED TIMBER

Timber is a circular and sustainable alternative gaining momentum, with proven value in compatibility, reversibility, and/or recoverability of interventions.

Several technical timber products are available to improve existing buildings' earthquake safety, increase load solicitation capacity and enhance comfort. Yet the (vernacular) connection with timber lost the scale it once had, and those trained in timber-related arts & crafts can't tackle all the needed daily "repairs", currently performed by unskilled professionals with suboptimal results.

Timber became a technical material that requires highly trained staff—from engineers to onsite workforce—to deliver guaranteed solutions. The timber-based frame with OSB-sheathing panels used in this paper requires studies currently only viable within academic contexts, as trained staff—diagnosis, design, fabrication, construction and maintenance—is still scarce and expensive.

Assuming that historic/existing buildings are mostly similar in neighbourhoods, this paper proposes that engineered timber must take part in wider views, to regain the ubiquity it once had across Europe.

1.2 DEEP RENOVATION

"Deep renovation will boost innovation and investments in the entire construction value chain. Deep(er) renovations imply a need for competence and technical knowledge of high efficiency solutions and processes. Increasing the rate of deep renovation is an opportunity to develop industrialised solutions to renovation and to create even more high-quality jobs and boost the green economy. If deep renovation policies gain appropriate support and become mainstream, the construction sector could experience an important and stable boost comparable to Europe's post-war reconstruction in the 20th century." [9]

This bright future is hanging on "appropriate support" and "mainstream" adoption, yet legislation and practice are targeting linear "demolish" and "rebuild" approaches.

Deep energy renovations are gaining legal prominence and are often presented as an end in themselves. Minimum Energy Performance Standards (MEPS) requirements for existing buildings, already a practice in some European states, are imposed on homeowners that, unaware of alternatives and without negotiation power, opt for what they can afford: gentrification or abandonment/collapse.

Although the term "Deep renovation" is still missing a legally binding definition in Europe, several studies referenced in [9] already point to existing definitions and practices across Europe that support this discussion.

This paper proposes that deep renovations must go beyond energy to "*gain appropriate support and become mainstream"*, to include instead of exclude, to get the scale necessary for mass customization and industrialized prefabrication, and to engage a new generation of highly skilled "green jobs" professionals.

1.3 POSITIVE ENERGY DISTRICTS

As per 2023, the energy performance requirements of new buildings in the EU are in rapid improvement. EU has proposed that from 2030 all new buildings should be built as Zero Emission Buildings (ZEB) and transform the building stock into zero-emission buildings by 2050. This wave of renovation represents an opportunity to improve also other building qualities, such as seismic resilience. However, to take advantage of the characteristics of groups of buildings rather than individual buildings, the literature suggests moving the zero energy objective from the building to the district level [10]. Similar considerations are valid for seismic rehabilitations in historical areas where there are structural effects between buildings that are not accounted for when structural interventions focus on singular buildings only [11].

Moving to a district level implies that the diversity in load profiles, production and storage capabilities can be utilized as well as the possibility of sharing costs and resources in the construction and operational phase of the buildings. The principles have been developed for several years, and already there is an EU-funded program aiming to support the planning, deployment and replication of 100 Positive Energy Districts (PED) by 2025 [12].

1.4 LEARNING FROM A HISTORIC BUILDING

The Montarroio case study, spotted in red in Figure 2, is a three levels masonry building already pictured in 14th-century maps of Coimbra, Portugal. It faces the UNESCO and "Jardim da Manga National Monument" protection areas, closing a row of similar buildings.

This building is composed of load-bearing masonry walls made of undressed stone blocks, thinner towards the top level (Figure 3), with growing internal floor areas: 13.7 m2 at the lowest level; 15.3 m2 at the intermediate level; 20.7 m2 at the upper level. As found in many ancient buildings renovated century after century, openings are not regular in dimension and location, and some windows were closed with a thinner layer of masonry at the upper level, leaving alcoves. This translates into irregular

https://doi.org/10.52202/069179-0532

masonry structural elements and discontinuous transmission of loads to the ground. The roof structure illustrates a 1980s low-quality "repair" of irregularly shaped eucalyptus structure "glued" to the walls using cement, which explains many of the rotten connections.

Figure 2: *Contextual view of Montarroio case study, spotted in red, and neighbouring area (Source: Google Earth)*

This extreme irregularity, illustrated in the sections in Figure 4 imposes so much uncertainty that it ends up as a scientific challenge; yet the lower floors are more than 600 years old, the top floor almost 400; and both survived a foundation settlement from the excavation of south-facing monumental stairs, provoking its tilt around 1980s.

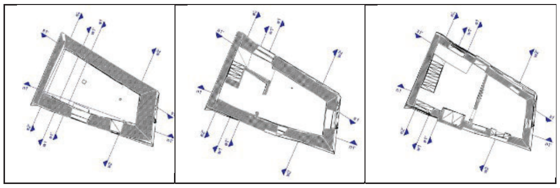


Figure 3: *Plans of the Montarroio case study (source: author)*

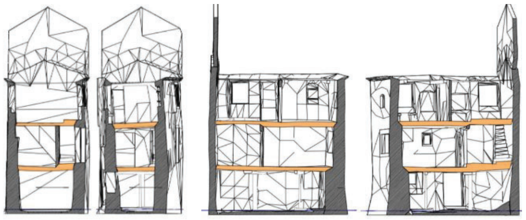
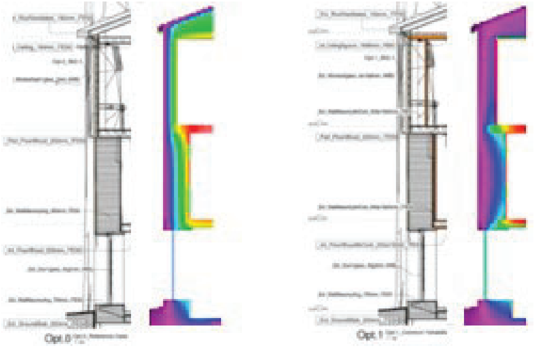


Figure 4: *Transversal and longitudinal sections of Montarroio case study (source: author)*

Visualizing thermal images allows a better grasp of the challenge and the risks of "improvements". Figure 5 shows a Building Information Model (BIM) and a thermal model illustrating the effect of interior insulation.

The original solution (a) displays a balanced "sandwich" of temperatures, cold to hot from the outside to inside, with asymmetries inside. The interior insulation (b) model presents stable indoor temperature, yet thermal stress in the floor connections. Low heat loss in insulated areas contrasts with punctual heated floor connections, enabling differential wet/dry and freeze/thaw cycles, and accelerated wall and timber degradation in those areas.



a) b)

Figure 5: *Comparison of the original situation (a) with an interior thermal insulation strategy (b) in a south wall section in a BIM model and thermal behaviour model using THERM* ***[13]****.*

2 TIMBER IN THE RENOVATION OF EXISTING STRUCTURES

This section tackles monothematic approaches to Seismic Renovation and Energy Renovation to demonstrate that the detailed processes they require have much to share.

The case study illustrated must not be seen as a guide, as it results from a limited number of views and assumptions. Nevertheless, the authors use this example to support debate and trigger new views and constructive input.

2.1 SEISMIC RENOVATION

Although Coimbra is not considered a high seismic risk area, this building has evolved through centuries with varied construction techniques, including timber floors and cross-layered timber walls that are probably the explanation for its survival. Nevertheless, it was subjected to significant changes, like the addition of an unbalanced bathroom in concrete, and risky "repairs" that make its´ stability questionable. The following study, documented in [14], tackles problems with assumed simplifications.

2.1.1 Stability refurbishment solution

The studied retrofitting technique consists of a timber-based frame (strong-back) and panels fixed to the internal side of walls using steel connections. The technique has been proposed and tested by Dizhur et al [15]], The result is a hybrid system where the two components, masonry and timber retrofitting, collaborate in resisting earthquake actions. Collaboration is ensured by mechanical bonding obtained through point-to-point connections. Posts act in flexure to transfer wall loads to the adjacent floor diaphragms, subdividing a large planar wall into several vertical buttressed segments. Posts are applied to the masonry wall and connected to it through steel angles (C2 and C3 in Figure 6 and to foundations or slabs through tie-down. In addition to such a system, horizontal nogging elements and OSB boards were added to increase also the in-plane capacity of masonry walls [14]. In-plane cyclic tests on retrofitted walls and shake-table tests on a full-scale retrofitted building demonstrated the validity of the chosen approach [16].

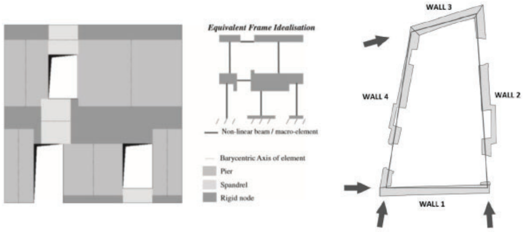
2.1.2 Mechanical model

The conceptual model was developed with the TREMURI computer program [17], an equivalent-frame macro-element model in which the wall structure is represented by an assembly of 2-nodes elements connected by rigid nodes. The macro-element model parameters rely on the experimental characterisation of masonry mechanical properties. If necessary, the use of non-linear beam elements allows the modelling of concrete curbs, wooden elements or reinforced masonry. Further technical detail can be found in [17].

Figure 6: *Example of strong-backs layout (Source:**[14]**)*

The "Equivalent Frame Modelling" approach is based on the identification of deformable structural elements that interact with each other through "rigid portions", connecting the two main macroscopic components. Piers, the main vertical resistant elements, hold both vertical and lateral loads. Spandrels, the secondary horizontal elements, couple the response of adjacent piers and allow or restrain rotations, significantly influencing walls' lateral capacity.

The retrofitted building has been modelled using a dense mesh and adding a non-linear beam as reinforcement. Posts have been located at both lateral ends of piers and with a spacing not higher than 0.9 m. The OSB panel contribution is modelled by increasing mechanical parameters of masonry shear strength.



(a) (b)

Figure 7: *Example of equivalent frame idealization for irregularly distributed openings (a)* ***[17]*** *and pushover directions performed (b).*

The seismic verification is carried out using pushover analysis, through the prescriptions suggested by the N2 procedure [18] [19] implemented in several codes [NTC18, EC8]. Pushover analysis is carried out under conditions of constant gravity loads and a horizontal load pattern with fixed distribution and controlled to monotonically increase the displacement of a control node. Four pushover analyses have been performed, parallel to each wall direction.

The verification consists of comparing the displacement capacity of the building with the seismic demand (in Coimbra a PGA of 0,07 g is expected for a return period of 475 years). However, the proposed analyses are valid also for evaluating the global behaviour of the structure before and after the retrofit intervention (local analysis, which should be evaluated with other tools that are out of the scope of this paper).

2.1.3 Results

The comparisons between unreinforced and strengthened masonry provide an idea of the potential of the retrofitting technique proposed.

Damage level in TREMURI software is represented through a graphic convention in which the cross shows the full development of a shear failure mechanism and straight lines at both ends of the element show damage caused by the flexural/rocking mechanism.

The shear damage level on each masonry element is identified through a chromatic scale in which red colour represents the achievement of the maximum shear resistance, while lighter colours identified the development of non-elastic sliding effects (see Table 1).

The result in terms of the capacity curve is reported in Figure 8 for wall 1 and pushover performed in Wall 1 Direction. In this case, the failure is reached for exceeding the flexural drift limit. Capacity curves show a remarkable increase in displacement capacity as well an increment in shear capacity.

Similar results obtained for the other cases in the analysis can lead to the following considerations:

- A significant (250%) increase in displacement capacity, of the whole structure and single walls, in pushover performed parallel to shorter walls
- Minor increments (10-50%) obtained along directions parallel to longer walls
- The retrofit intervention involves changes in the failure mechanism
- Lateral strength capacity increased in all directions in a range of 50-80%.

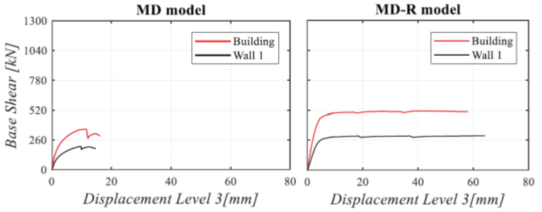


Figure 8: *Comparison of capacity curves between the entire building and Wall 1 of pushover performed in Wall 1 direction for unreinforced model(left) and strengthened model (right).*

To facilitate the comparison of the study [14] results Table 2 illustrates the pushover damage in unreinforced masonry walls, while Table 3 illustrates the added value of an engineered strengthening of these masonry walls.

Table 1: *Percentage variation of maximum shear and displacement of the unreinforced and strengthened models.*

	Base shear variation	***Displacement*** variation
Push_1	+ 72 %	+ 262 %
Push_2	+81 %	+ 10 %
Push_3	+ 53 %	+ 246 %
Push_4	+ 89 %	+ 58 %

Numerical modelling demonstrates that the proposed retrofit solution increases displacement capacity and base shear capacity, with a change of failure mechanism. That means collapse may be reduced due to a brittle mechanism favouring a more ductile behaviour, increasing seismic safety. Later in this text, the importance of a neighbourhood approach to adequately quantify and qualify several parameters will be highlighted.

Table 2: *Pushover damage in **Unreinforced** masonry walls*

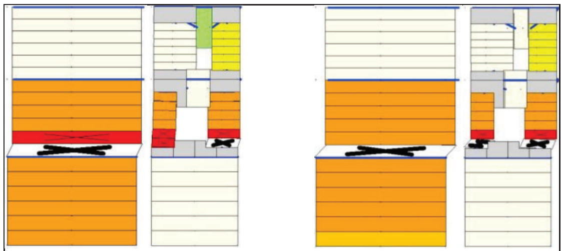


Figure 9: *Damage on **unreinforced** pairs w1(W) /w3(E) from **pushover** performed in **w1**(left) and **w3**(right) directions*

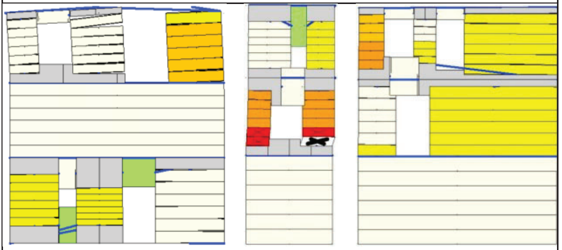


Figure 10: *Structural damage on **unreinforced** walls w2(S), w3(E) and w4(N)from pushover in w2 direction*

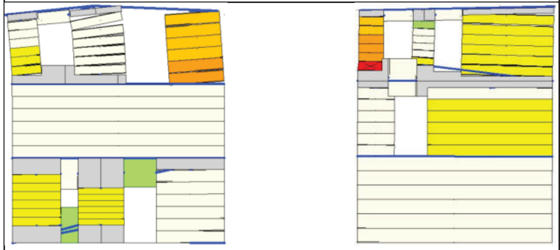


Figure 11: *Structural damage on **unreinforced** walls w2(S), and w4(N) from pushover in w3 direction*

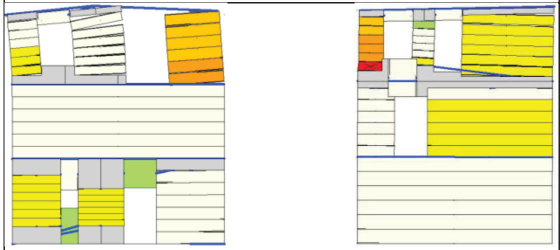


Figure 12: *Structural damage on **unreinforced** walls w2(S), w3(E) and w4(N) from pushover in w4 direction*

Table 3: *Pushover damage in **Strengthened** masonry walls*

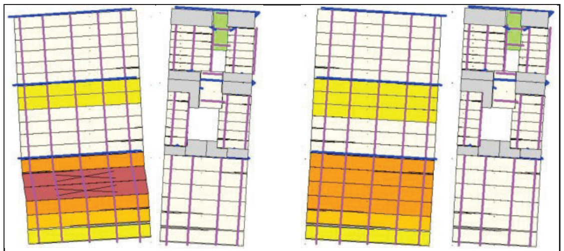


Figure 13: *Structural damage on **Strengthened** pairs w1(W)/w3(E) from pushover performed in w1 (left)* **and** *w3 (right) directions*

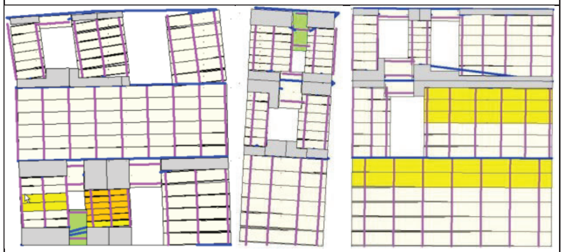


Figure 14: *Structural damage on **Strengthened** walls w2(S), w3(E) and w4(N) from pushover in w2 direction*

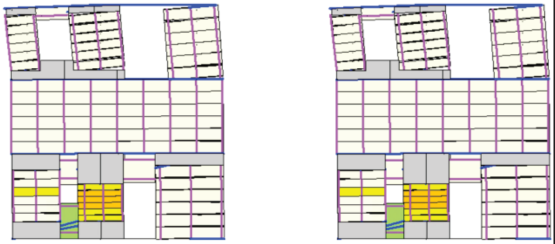


Figure 15: *Structural damage on **Strengthened** walls w2(S), and w4(N) from pushover in w3 direction*

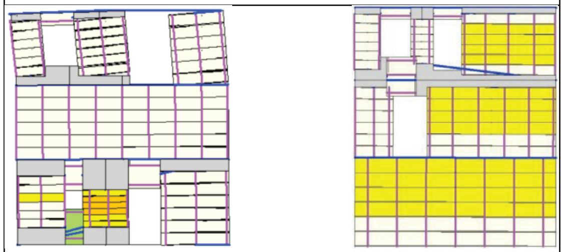


Figure 16: *Structural damage on **Strengthened** walls w2(S), w3(E) and w4(N) from pushover in w4 direction*

2.2 ENERGY RENOVATION

Figure 17 maps Energy Performance Certificates (EPCs) issued around the case study, spotted in red. Investigation [1] demonstrated that between 2012 and 2022 only one-third (25 out of 76, those with letters overlaid) had EPCs, issued by 13 different experts on different dates and with varied levels of detail. The EPC process often implied two interactions: one EPC requested by the initial selling part—before advertising for sale, so unaware of buyers' or tenants' objectives— and, after renovation, another EPC per legally designated fraction.

The EPC process implies a) an initial service request by the original owner, b) collection of necessary legal data, c) a site visit to diagnose geometry and constructive solutions, d) calculation of a compared "baseline" according to current EPC rules[4], e) diagnosis of the needs and potential of the building, preferably produced together with the client f) identification and calculation of 10 improvement measures viable for this specific fraction, g) consultation of local availability and prices for evaluation of cost/return ratios, h) photos with scaled targets of all divisions and acclimatization equipment with ID tags i) preparation of reports with detailed constructive solutions and thermal bridges discretization, j) insertion of data in the EPC site, k) emission and payment of the EPC and m) explanation to the client.

The improvement measures proposed must follow the EPC portal typification for the whole country, from north to south: demand reduction by adding insulation, replacing single pane wood frame windows for highly efficient double pane glazing; efficient use of energy by electrification using (air-water) heat pumps; and renewable energy production at the end of the priorities.

The split-incentive barrier —requesting an EPC to a seller who pays the costs for benefits that might accrue to the new buyer or tenant—often results in a "lowest cost" market, with excessive simplifications often resulting in EPCs that miss the potential of the building and neighbourhood they sit in.

This mismatch explains a "re-issue" feature in the EPCs portal: only improvement measures listed in each EPC are accepted for financing, forcing candidates to request a new EPC mentioning those desired measures: another cost/difficulty to access prepaid[5] unguaranteed financing.

__Figure 17:__ In 10 years only 33% of these buildings were certified and most "rehabilitated" do not excel in performance. Source: author sketches over local GIS and Google maps.

As all buildings in Figure 17 are inside a protection zone, exterior insulation is forbidden, the interior is not realistic for such small areas, and other limitations apply.

2.2.1 Reducing envelope energy demand

The effect of placing expanded cork in the hollow parts of the strengthening timber mesh proposed in 2.1.1 is illustrated in Table 4. A width of 0.05m, inferior to the available space, was chosen to avoid excessive U-values difference between the timber studs and cork, but studies are advised to evaluate the risk of condensation spots.

***Table 4:** Effect of inserting 0.06m of expanded cork within the structural mesh proposed for the seismic retrofit.*

Wall width	Original U-value (W/(m².ºC)	U-value with 0.05m insulation (W/(m².ºC)
Level 2 (0,25m)	2.52	0.64
Level 1 (0,6m)	1.4	0,53
Level 0 (0,9m)	1.01	0,46

As for the windows, the estimated U-value defined for single pane windows is 5.1 W/(m².ºC) can be reduced to 3.4 W/(m².ºC) if low airflow external shutters exist. Installing a certified "Classe+" window, the only type financed in Portugal would ensure a U of 1.5 W/(m².ºC). Although these values may seem attractive to "improve" the envelope, an uncontrolled approach would reduce the available useful area and cancel the thermal delay: this would impose regular use of devices for heating and cooling that were previously unnecessary.

The same is true for airtight windows, as stopping infiltrations implies ventilation with extractors or self-regulated grilles: "if you build it tight, ventilate it right". Reducing envelope demand would increase dependence on equipment for heating, cooling, and ventilation, refuting the thermal resilience proven over centuries.

2.2.1 Reducing fossil energy demand

Energy loads such as domestic hot water and acclimatization are sure targets for improved efficiency. Contemporary improvement measures for domestic needs in this building would include improved efficiency water taps (more pressure with less hot water, a dual gain), better efficiency gas boilers and air-water heat pumps, together with similar systems for acclimatization.

In this area, external heat pump evaporators are not allowed, and air-water heat pumps occupy the scarce interior space available. Solar panels are allowed on the roof, but the unknown capacity of these old structures makes installation & maintenance risky in these buildings [1]. Efficient fossil-fueled equipment is both the least expensive/spacious, thus often the chosen solution.

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[4] The EPC rules assume that the building is entirely and permanently acclimatized, not reflecting actual Portuguese habits of partial heating in a mostly mild climate [1].

[5] The current support mechanism requires families to invest first, and request funding after the investment is complete.

3 DISCUSSION

Engineered timber's role in deep renovation is dependent on a wider recognition of its arguments. Similarly looking solutions in amount, type and costs can use timber to hold insulation to walls or to deliver engineered improvement, yet only the second can add proven safety to owners/users: there is a value in knowledge. On the other hand, the costs of timber engineering/architecture are hard to charge for a single building, as the efforts for a correct diagnosis, study and design are still expensive, making them rare. The individual approaches to seismic and energetic renovation reported above show space for savings through base model optimizations for these and other future needs.

Yet going further opens new possibilities, as documenting a neighbourhood—often a repetition of construction techniques/materials within a limited area—allows for scaled holistic views, new visions and new strategies.

Departing from a current limitation—individual linear flows underlying energy guidelines/financing schemes—it is proposed that scale, with communities, can deliver what the EU needs: real decarbonization, energy security/poverty prevention, resilience, and a circular economy—with engaged citizens.

3.1 FROM LINEAR TO CIRCULAR ECONOMY

Circular economy combines the reduction, reuse and recycling activities through systemic shifts aligned with sustainable development. A circular intervention must follow the three dimensions of sustainability—economic, environmental and social—to deliver prosperity, environmental quality and social equity [20].

Although proclaiming circularity, many European public financing excludes maintenance/optimization of existent solutions or systems; like the windows referred to above. In Portugal, a window replacement can apply for 70% of public funding if such "improvement" is mentioned in the EPC and the original is replaced by windows classified as "Classe+", with a U-value of 1.5 W/(m^2.ºC). This implies the removal, transportation to a dump site, and all the embodied energy needed to produce/fit the new window into an often-irregular casing: more risks, and added costs. Retrofitting the existing windows can deliver similar results, as shown in Table 5, which depicts scientifically validated values [21] for some window retrofit solutions.

Table 5: *Extract from the "Research into the thermal performance of traditional windows: timber sash windows" comparing the results of several window retrofits [21]*

Details of the test assembly	Glass only: W/(m^2.ºC)	Glass & frame W/(m^2.ºC)
Window as found	5.3	4.3
Heavy curtains	3.3	2.5
Well-fitting shutters	2.0	1.7
Reflective roller blind	1.8	1.9

These values show that circular economy approaches in windows improvement can deliver results while 1) promoting local maintenance and optimization practices, 2) reducing waste and fostering reuse practices, alongside reduced embodied energy, thus 3) fostering sustainable practices—economic, environmental and social— and green jobs able to "spill" to neighbouring buildings.

However, it is more attractive for a private owner with investment capacity to buy a new window for which a grant of 70% may be attributed, instead of spending half of the economic cost retrofitting the existing window. Although having similar levels of performance, these improvements are not homologated by "Classe+" scheme, thus not recognized by the certification entity.

3.2 LINKING ENERGY TO COMMUNITIES

The current urge for electrification— heat pumps, electric cars, and modern electric gadgets—requires either a significant electric network capacity improvement, and/or local renewable production, and/or ICT connections for "virtual power plants" to turn off non-urgent energy needs (water heaters and other postpone-able energy uses) in exchange for retribution for delayed availability.

Instead of requiring homeowners to request an individual EPC, a neighbourhood pre-certification can be offered to overcome split-incentive issues, study scenarios and trigger action. District heating, renewable energy communities and other solutions already funded rarely find the collective necessary to proceed, and to upgrade a neighbourhood into a Positive Energy District.

3.3 ON THE VALUE OF NEIGHBOURHOOD APPROACHES

Scale is often necessary to deliver complete solutions.

The seismic reinforcement strategy presented is limited without out-of-plane (overturning) analysis of common walls. Figure 18 illustrates a study analysing the whole block [11] to characterize the effect of shared walls in the neighbourhood seismic behaviour.

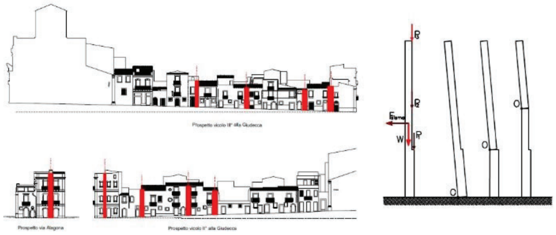

Figure 18: *Image illustrating 9 common walls analysed for overturning in a neighbourhood-scale seismic study [11].*

The energy efficiency neighbourhood scale approaches [1] also facilitate holistic thinking: is it wise to place solar systems in each of these unknown structural capacity roofs—without adequate access to the roof, thus implying cranes for installation and maintenance—when a unified space is available[6] in the blue areas in Figure 17?

Neighbourhoods have the scale and regularity for integrated diagnosis, planning and execution, as defined

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[6] This proposal, named "Common Efficacy" was validated by the 2015 VINCI Innovation Awards (4mn video available) [22]

https://doi.org/10.52202/069179-0532

by EN16883 on "Guidelines for improving the energy performance of historic buildings".

Scale attracts new business models, and optimized learning curves while lowering contextual costs, from planning to maintenance, operation and optimization. Making it with local communities closes the circle, fostering new green jobs and the confidence necessary for sharing data in common initiatives.

Renewable Energy Communities are changing the landscape, as some support is already available for the design and implementation of neighbourhood-scale energy systems. Similar supports must be attributed to foster deep renovation strategies, and those will probably be first attributed to lower-income areas.

3.4 HOLISTIC DEEP RENOVATIONS

By 2030 the Renovation Wave aims to double the energy renovation rate and foster deep energy renovation uptake, meaning that "By 2030, 70% of the renovations taking place should be deep" [9].

Multiple benefits, from microeconomic to social, are referenced. From reduced bills/exposure to volatile fossil energy prices to improved Indoor Environmental Quality (IEQ), comfort, well-being and productivity, reduced morbidity and mortality during extreme phenomena, to new green jobs, the advantages are many but not always linked to the proposed metrics.

If deep renovations are to deliver Climate Change mitigation and adaptation—from lower carbon emissions to flexibility on demand, from distributed production to increased resilience and guarantee basic energy services while "*including poorer health and lower levels of social inclusion"* [5]—then the industrialized solutions anticipated require holistic views and a solid legislative background to start moving.

3.5 LINKING ENGINEERED TIMBER TO COLLECTIVE CHALLENGES

It is probably strange to suggest to highly qualified engineered timber professionals that part of their future success may reside in helping the lower levels of society fight (energy) poverty, bad living conditions and safety risks at a time when engineered timber is engaged in high-level design and construction challenges.

Yet the engineered timber sector faces significant challenges—from insurance added costs to concerns on construction and maintenance crews and limited investment for industrialization—to which a European-wide interest would be appreciated.

The advantages of engineered timber are significant: dry and quick onsite responses to energy and safety issues, potential for integral/stagged deep renovation to include natural trigger points, and the use of an endogenous european material enriched by knowledge, among others. With such edges in this emerging context, will the sector continue waiting for occasional orders, or take the lead, subcontracting the easy parts—infrastructures, systems, renewables—to other partners and stakeholders?

4 CONCLUSIONS

Scaling up timber-engineered supported strategies in neighbourhoods can deliver sustainable, inexpensive, and holistic deep renovations aligned with 2050 goals.

The contemporary individualist monothematic strategies in place to solve collective issues conceptually contradict the Beautiful | Sustainable | Together"[7] European goals.

Holistic deep renovations, at the neighbourhood scale, can deliver more—energy efficiency, (seismic) safety, quality of life, comfort and community well-being—with lower economic, social and environmental costs.

Neighbourhoods, characterized by their repetition, similarity, complementarity and interdependence, have the scale to optimize processes and reduce design, contracting, operation, maintenance and optimization costs; and trust is essential for sharing the resources and information required to achieve Positive Energy Districts.

Future-proofing neighbourhoods with climate adaptation and anticipation—a practice in which the sector has significant experience—can make a difference in most European historic centres, and in many countries that look to Europe as an example. And providing added safety, circularity and sustainability is of no minor importance.

Engineered timber strategies facilitate multistage deep renovations able to match the financial capacity of owners and users with natural trigger points of existing materials and equipment, making the most of historic areas without requiring excessive initial investments. Decarbonizing energy needs, fostering local renewable energy production and peak management generates income for investment payback and other sustainable interventions.

Low embodied energy deep renovations and circular maintenance/optimization procedures must be recognized /funded across Europe. By delivering solutions to wider problems in partnership with other stakeholders, and by defining viable roadmaps, the sector can lead the huge market of deep renovations; and their optimization.

The engineered-timber sector must demonstrate that an endogenous economically, environmentally and socially sustainable material, enriched by knowledge, can redefine the future of deep renovation.

ACKNOWLEDGEMENTS

This research evolved with the support of the "Sustainable Energy Systems" University of Coimbra/MIT Portugal Program (SFRH/BD/51017/2010 FCT grant) and engaged commitment of modular, arq:i+d, lda, Snapmaker & TUCAB (https://snapmaker.com/) (https://www.tucab.pt) for the models to be displayed in the conference. Part of the work presented in the paper was carried out within the framework of the WP5 "Low-impact and integrated rapid execution interventions" of the ReLUIS Research Programmes 2019-21 and 2022-24 funded by the Italian Department of Civil Protection.

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[7] New European Bauhaus: https://new-european-bauhaus.europa.eu

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