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People-centred deep renovation practices: from challenges to strategies

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Highlights

The issue of deep renovation and its impact on building energy use is a highly complex problem, which is not necessarily only influenced by technology-driven measures or technologies. With this paper, we argue achieving the global energy efficiency and carbon reduction goals in the building sector must be achieved by unlocking an interdisciplinary understanding of the "human dimensions" of deep renovation practices.

Abstract

This paper bases its considerations from the refusal of the prevailing perception that buildings consume energy, and assumes, on the contrary, that it is actually people, that consume energy for their comfort. This means that it is necessary to identify the end users' behaviour, actions and habits in relation to the use of energy and their way to make decisions regarding energy retrofit interventions. This should be done considering also the economic savings and the costs, health and wellbeing of people as important drivers in the decision-making process. To do so, in this paper, we will try to position the main challenges encountered by users in the deep renovation first, hence disclosing some possible strategic actions for the uptake of a people-centred revolution of the renovation market in EU.

Keywords

Deep renovation, Social aspects, Financial and economical barriers, Technical challenges, People-centered approach, Human dimension, Energy efficiency

1. INTRODUCTION

It has been highlighted that the existing built environment is currently responsible for 40% of total primary energy demand and 36% of greenhouse gas emissions in Europe. To lower emissions and mitigate climate change, this demand needs to be reduced. To understand the scale of the challenge, the existing building stock counts 210 million buildings [1]; this is an occupied space equivalent to the size of Belgium. In addition, 90% of these buildings are estimated to still be standing in 2050. With the replacement rate of the existing building stock at only 1-2% per year, energyfocused renovation will be the primary means of carbon emission reduction [2]. The current processes of building renovation towards NZEBs are often time, labour and materially

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inefficient [3]. As such, there is a significant opportunity to create new ICT processes, for the renovation industry, which incorporates the design, manufacturing, construction, material choice, operation and end of life phases affecting the overall building lifecycle [4–7].

Deep Renovation [8–12] refers to energy renovation processes involving the full energy efficiency potential of improvements, thatcombineeseveral necessary measures in one strategy, instead of focusing on single standard actions (i.e. windows replacement, wall insulation, new generator with greater performances, etc.).

Including ICT in the overall building process is seen as one of the most important triggers for the modernization of the construction sector [13]. Innovative projects are currently supporting the transition to a modernized building construction approach, by using ICT as the means of achieving an inclusive reorganisation of an unsuitable and non-optimized building construction process [5,6,14]. The objective is to reduce the responsibility of the building sector on climate change through industrialization, sustainability, affordability and ICT-enabled production innovation. However, ICT alone will not be enough without rethinking the whole construction value chain. No disruptive ICT-enabled modernization at the level of the construction sector will succeed in penetrating the EU market without including public acceptance and perception of innovative building solutions [15]. As such, the understanding and support of users over the whole construction process, from design to end of life will be core to innovative projects and solutions [16].

Over the last yeast, researchers, policymakers and practitioners in the field have been led to think the buildings as the subject of energy consumption by the recurring statement that "Buildings in the EU use almost 40% of final energy"[17]. This paper tries to overcome this concept, assuming that it is actually people, and not buildings, that consume energy for their comfort [16,18]. This basic idea from Janda et al., [19], leads to focus on the understanding of the human factors of building energy usage, and the effective involvement of key stakeholders on the best practices to be adopted for the energy redevelopment of buildings. Innovation must break through the traditional building design and construction process, making it more sustainable, faster, cheaper, safer, reliable and more tailored with respect to users' needs, compared to current state of the art. This optimization mission will be empowered by a user-centric digitalized and industrialized construction process, providing ICT-enabled experience to key stakeholders involved during the whole building lifecycle.

2.CHALLENGES IN THE EU DEEP RENOVATION MARKETS

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This paper is addressing the main challenges in the EU market for the uptake of ICT enabled, sustainable and affordable building renovation practices as follows:

1. Improving acceptance, usability and co-design of advanced retrofit solutions leveraging on SSH (applied anthropology, social psychology, behavioural research) to understand public perception and acceptance of innovative product and process. Key stakeholders responsible for the market uptake of such modernized building construction process in EU must be involved from the early design phases to the dissemination activities.
2. Solving the fragmentation of renovation industry across various disciples, by providing fully-integrated BIM-based building optimization, simulation and visualization platform, that supports relevant stakeholders involved during the whole construction process, starting from the design phase, and after the renovation took place.
3. Providing ICT-enabled environmental, energy, economic and social benefits to the total renovation process through market-ready plug-and-play modular construction packages including smart building components, materials and technical systems (for deep renovation or new construction) and hardware and software technologies.
4. Demonstrating large-scale replicability potential of the innovative renovation solutions, grounded on demonstration cases deployed across relevant EU geo-social clusters.
5. Proving data-driven evidence of the technical, social and economic viability of the innovative retrofit solutions, including:
   - performance certification (mechanical, safety) of innovative material and components characteristics to support improvement of current EU standards and regulations for advanced construction solutions, validated by standardization bodies;
   - environmental certification of innovative smart materials, components and prefabricated modular solutions fostering circular economy through LCA assessments;
   - improved IEQ and wellbeing demonstrated by voluntary-based certifications;
   - industry-driven business models.

3. A STRATEGY FOR DEEP RENOVATION PEOPLE-CENTRED INTERDISCIPLINARY APPROACH

Innovative retrofit processes must involve inter-disciplinary considerations and use of stakeholder knowledge [20]. In order to establish a strong framework for supporting the user-centric approach, innovative projects must engage an interdisciplinary set of expertise (engineering, sociology, behavioural research, anthropology, economics) to fully value the ambitions and expectations of users, taking into account the barriers in the take-up of ICT-enablement and off-site solutions, also in traditional work environments such as the construction work-force [21–23].

A number of relevant European projects have addressed several of these barriers separately. Building upon these results, this study has the ambition of highlighting such this innovation potential, with a systemic approach described in Table 1 as follow.

Most crucial issues in the European construction sector	Addressed by state of the art projects	Innovation Actions beyond the SoA
The European building sector is not able to offer systemic solutions for life-cycle integrated performance control, due to a lack of reasonable costs and good quality. This leads to a lack of clear view on the total performance in practice, as well as solid control of the quality of products and construction processes	MOEEBIUS INSITER E2DISTRICT OptEEmAL	Integration of an ICT-enabled building construction process over the entire building lifecycle to reduce the performance gap
The European building process is typically based on a fragmented 'layered' structure, with many labour actions during the design phase, on the buildings site, sub disciplines involved, leading to extra costs, time, and failure risks	New TREND Energy in Time	Full integration of a BIM-based construction system in the design, manufacturing, construction, operation, maintenance, commissioning and certification, starting from audit of the existing situation, up to the building's end of life
The European building market is typically top down and supply-driven, with a mismatch between the offered products and the building industry end-users needs and the consumers' affordability	Triple A-reno PROF/TRAC MOBISTYLE ALDREN LEEMA	Adopt user-centric design approaches to understand public perception and acceptance of advanced retrofit solutions among different stakeholders responsible for the market uptake of a modernized building construction process in EU.
Traditional construction methods are not able to plan in advance all the problems to be solved during the retrofit process in the variety of renovation sites	P2ENDURE	Develop a monitoring kit to perform the audit of the existing situation including building systems (geometry 3D scanning, comfort and IEQ measures), and occupant behaviours.
The European renovation market lacks affordable tools on decision support to involve designers and end-users in attractive and effective building retrofitting process.	New TREND UMBRELLA	Develop vertically integrated life cycle ICT solutions that support the end users during the whole construction process, starting from the design to the end of life.
Poor energy performance of EU building stock is due to the use of traditional or unsuitable construction components and process	MORE-CONNECT ProGETonE IMPRESS BRESAER	Increased level of ICT-enabled industrialization of the building construction process, including integration of smart components, lean construction and higher degree of prefabrication

Table 1. Innovation potential for people-centred renovations.

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4. FROM CHALLENGES TO INNOVATION STRATEGIES

In recent years, numerous EU projects have tackled the technical aspects of deep-renovation through the search for innovative technological solutions to overcome the obstacles present in the market of energy requalification[15]. The main barriers that have been found in the deep renovation processes follow under one of these three categories [24]:

- Economic and financial barriers;
- Technical barriers;
- Social barriers.

As for the economic and financial barriers, they are essentially given by):

i. High up-front costs and owners reluctant to borrow funds for energy renovation purposes;
ii. Long pay-back times of retrofitting interventions;
iii. Lack of confidence of the potential investors;
iv. Insufficient and unstable available funding;
v. Lack of attractive financing for homeowners with low to medium incomes who are usually not eligible for regular bank loans;
vi. The fact that existing financial tools are insufficient and unattractive.

As for the technical barriers, they include:

i. Lack of consistent and standardized solutions or integrated solutions to comply to new and different building standards requirements on energy saving;
ii. Lack of skilled workers to carry out the work;
iii. Shortcomings in technical solutions and long process discouraging owners;
iv. Safety/seismic risk connected with the deep renovation processes (damages can be done to the homes while retrofitting or unsure perception of the current safeness in the existing buildings);
v. End users' and owners' lack of technical expertise and trust in effective energy renovation savings.

Finally the main social barriers include:

i. Decision-making processes that are long and complex, especially in case of multi-owner houses (condominiums);
ii. The lack of consensus, understanding and support from the inhabitants that often hinders the effective approval of the interventions;
iii. The problem of disturbance during site works and/or relocation (in case

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owners/users need to leave their homes during the process);

iv. Low awareness about energy efficiency and non-energy benefits of renovation; v) - Lack of dialogue between the different stakeholders.

As a consequence, there is a strong need to create strategies to strengthen the people's confidence and accelerate the market of deep renovation [24]. In the following section, five key challenges from the social, technical and financial perspective are highlighted. For each of these, some crucial objectives are listed, to be implemented in strategic innovation actions.

4.1. TECHNICAL CHALLENGE

Challenge 1: Lack of cost-effective, high-quality systemic solutions for life cycle design, leading to an unclear understanding of real performance and poor control of construction and products and process quality

Innovation 1: Development of web-based platforms for analysis of data from the sensor network and onsite app for forecasting and building services. These online platforms shall also be deployed with KPI-driven analytics for reliability-centred maintenance planning.

Strategy Objectives 1

- Understand the current state of existing buildings with respects to architecture, energy use, IEQ performance, and user behaviour;
- Manage and collect data from all phases of a building's life to generate useful information for understanding and decision making over the entire building life cycle;
- Optimise the use of the building and its systems for enhanced user comfort and cost-effective energy use; generate clear messages to meet user-defined goals;
- Reduce operational costs through continuous commissioning; enable informed retrofitting planning.

Challenge 2: Fragmented traditional construction process: sub-disciplines are involved at different moments and locations lead to extra costs, delays, and to risk of failure

Innovation 2

- Design Platform: Interconnected suite of tools for targeted analysis and performance-oriented optimisation of concept, detailed and construction

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design;

- Plug & Play Module: Industrialised, off-site lean construction solution integrating a variety of façade and HVAC functions with ICT sensing capabilities.

Strategy Objective 2

- BIM processes and solutions: Leverage vast amounts of data available as a baseline for iterative design, document creation and component production;
- Industrialisation in construction: Foster cost-effective solutions for deep renovation and new construction; support data-driven production in Industry 4.0 paradigm.

Challenge 3: Conservative approach of construction companies with respect to product and process innovation

Innovation 3

- Solutions integration: Source prototypes interconnected for integrated deployment and near to market;
- Validation in real life pilots: Deployment of the solutions across different sites representing a variety of Europe's residential stock across pilots in geo-clusters both in manufacturing and installation.

Strategy Objective 3:

- Cost-effective prototypes;
- Advance state of the art prototypes from previous research to a market-ready level;
- Demonstrated replicability from design to end of life;
- Prove the cost and time effectiveness of the innovative solutions against traditional on-site construction; demonstrate flexibility and reduction of development risk.

4.2. FINAL CHALLENGE

Challenge 4: Top-down market: cost and performance mismatch between supply from producers and demand from industry end-users and consumers

Innovation 4

- Support for new standards: Contribute to international definition and updates of regulation for ICT-aware, lean construction solutions;
- Development of Data-driven performance certifications;

- Development of people-centred business models;
- Roadmap for investment in affordable, sustainable advanced building solutions.

Strategy Objective 4

- Foster market and regulation;
- Communicate the transformative value of innovative deep retrofit solutions;
- Lower barriers for advanced solutions in standardisation and certification schemes;
- Develop industry-driven, user-centred business models that are technically and economically viable.

4.3. SOCIAL CHALLENGE

Challenge 5: Complex decision-making processes for renovation lead to poor capacity to involve effectively designers and end-users

Innovation 5: People-centred research adopting approaches from Social Science and Humanities (SSH) to provide a clear understanding of practices, barriers, needs and requirements; inform development of solutions to ensure the optimal user experience.

Strategy Objective 5

- Involve all stakeholders in attractive and effective building design and retrofitting process;
- Provide affordable, user-friendly tools for decision support;
- Understand needs at all levels of the value chain, including end-users.

5. CONCLUSIONS AND KEY TAKEAWAYS

The building construction sector has the potential to act as a smart system towards a more sustainable and affordable energy performance paradigm of the European building stock [25,26]. This sector must encourage the accelerated uptake of people-centred and ICT-enabled technologies, with a consequent demand-side reduction of energy use, carbon emissions, and operating costs while increasing the comfort, satisfaction, health, and productivity of building occupants [27,28]. Furthermore, an innovative retrofit process must include measures taken for public/societal engagement on issues related to the project [29–32]. Innovative projects must demonstrate the potential of the developed

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technologies engaging relevant stakeholders in co-creation and feedback before scale up and involvement of larger investments [18]. This can take the shape of thematic focus groups, dedicated hackathons or ideas contests [16,33].

People-centred innovation actions that go beyond the state of the art solutions must be developed and nurtured in the EU market, to address the most crucial issues in the residential construction sector [16]. In this perspective, some key lesson learned must be kept relevant for further research and development agendas:

- Innovation must break through the traditional building design and construction process, making it more sustainable, faster, cheaper, safer, reliable and more tailored with respect to users' needs, compared to current state of the art.
- This optimization mission must be empowered by a user-centric digitalized and industrialized construction process, providing ICT-enabled experience to key stakeholders involved during the whole building lifecycle.
- The suite of user-centric renovation solutions must be piloted in residential refurbishment and new construction programs to demonstrate measurable large-scale replicability of economic, social and environmental expected impact, from design to end of life.
- The exploitation plan must include the rollout of the off-site manufacturing in Industry 4.0 production lines, validation in industrial and laboratory mock-up facilities, and on-site installation in strategic building typologies in relevant EU geo-social clusters.

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