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4RinEU: Robust and Reliable Technology Concepts and Business Models for Triggering Deep Renovation of Residential Buildings in EU †

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Abstract: Only 1.2% of the EU building stock is renovated every year, and the rate is even lower in case of deep renovation (i.e., savings exceed 60% compared to pre-renovation levels), since such interventions are often too expensive. To answer these challenges, 4RinEU will define robust, cost-effective, tailorable deep renovation technology packages supported by usable methodologies, feeding into reliable business models. The project will manage different stages of the deep renovation process, from the preliminary audit up to the component end-of-life, and will provide information on energy, comfort, users' impact, and investment performance. The 4RinEU deep renovation strategy is based on 3 pillars: (i) technologies, to decrease net primary energy use (60 to 70% compared to pre-renovation), ant to reduce the life cycle costs over 30 years (15% compared to a typical renovation); (ii) methodologies to support the design and implementation of the technologies; (iii) business models to enhance the level of confidence of deep renovation investors.

Keywords: deep renovation; construction; business models; renewable energy sources; building information modeling

1. Introduction

A large part of Europe's building stock is inefficient in terms of energy use, mainly because of excessive heat losses through building envelopes, lack of efficiency of the HVAC systems and low exploitation of the renewable energy source potentials. Nevertheless, only 1.2% of the EU building stock is renovated every year, and the rate is even lower for deep renovation (i.e., savings exceed 60% compared to pre-renovation levels), since such interventions are often too expensive. Energy Efficiency Financial Institutions Group [1] recommended the development of common set of procedures and standards for energy efficiency and building renovation underwriting for both debt and equity investments. It asserted that several renovation technologies are available but the application is limited because of different key barriers:

- **Technical**: lack of easy to apply, integrated, tailorable packages;
- **Social**: no easy access to information on right behaviours, best practices and strategies for achieving environmental comfort and saving energy, lack of commitment of the users;
- **Credibility**: uncertainties in term of actual performances and costs as well as responsibilities in case of delay or failures;
- **Financial**: lack of access to affordable finance to carry out the renovation.

IEA estimated that applying the current policies and common practices, less than 20% of the economically viable energy efficiency investments will be realized within 2035 [2]. Therefore, there is a clear need of robust concepts and reliable approaches to increase the investors' confidence and to up-scale the energy efficiency investment. In order to address these challenges, the H2020 project 4RinEU (http://4rineu.eu/) is defining robust, cost-effective, tailorable deep renovation technology packages supported by usable methodologies, feeding into reliable business models.

2. Research Pillars

4RinEU will minimize failures in design and implementation, manage different stages of the deep renovation process, from the preliminary audit up to the end-of-life, and provide information on energy, comfort, users' impact, and investment performance.

In particular, 4RinEU deep renovation strategy is based on three pillars: robust technologies, usable methodologies and reliable business models addressing the following challenges:

- *Technology* development: to improve key passive, active, and control solutions, to optimize the integration and interactions among building components in dynamic contexts, to ensure a drastically reduction of net primary energy use (60 to 70% compared to pre renovation levels), ensuring high indoor environmental quality and architectural value, with reduction of lifecycle costs (15% compared to a typical renovation).
- *Methodology* development to support the design and implementation of robust, tailorable, cost-effective deep renovation packages in different boundary conditions, through multi-objective optimization, ensuring reduction of implementation time (by a factor of 2 compared to typical renovation through prefabrication and specific solutions for the management of the building site), and keeping the same performance level in the whole building lifecycle.
- *Business models* development to trigger EU building stock transformation, durably increasing the renovation rate up to 3% before 2020, as fixed by "renovate-Europe" campaign. This will be sustained by a reliable economic viability of deep renovation, quantified by an increased internal rate of return.

The effort within 4RinEU in the development of robust technologies and usable methodologies is the key to build the concrete foundations for the definition of reliable business models, that we identified as the mean for convincing to invest resources in buildings deep renovation.

A 4RinEU business model is meant as a comprehensive framework, including (i) costs, (ii) benefits, (iii) role and responsibilities of the stakeholders, (iv) technical and economic level of risks making uncertainties explicit, as well as (v) possible contingency plans. It will be the driver towards deep renovation, supporting the key decision on when/why/how/to renovate a building. The key concept is to structure technological and methodological knowledge to provide clear information to the stakeholders to increase the level of confidence, enhancing the awareness on the cost-effectiveness of the renovation, and then fostering the spontaneous investments.

3. Expected Outcomes

Constituting the backbone of the cost-effective deep renovation packages that include both innovative solutions and products already available on the market. There are 10 distinct objectives of the 4RinEU project, which reflect the 3 research pillars and context for the demonstrations:

3.1. Technologies

4RinEU demonstrations deploy technological innovations that will:

- reduce energy demand (1-Prefabricated Multifunctional Façade; 2-Comfort Ceiling Fan Smart Operation),
- improve energy efficiency (3-Plug&Play Energy Hub–PPEH; 4-Early-RENo),
- improve building operations (5-Sensible Building Data Handler), and
- reduce the construction waste (6-Strategies for Components End-Of-Life).

3.2. Methodologies

4RinEU intends to support the stakeholders along the whole renovation process, helping to:

- better understand the context, potential savings and issues to be addressed during the renovation (7-Cost-Optimal Energy Audit),
- handle an aware and transparent design approach easily include 4RinEU deep renovation packages (8-Investor and Building User-Oriented Design Platform), and
- manage in a lean way the construction works reducing time and the associated failures (9-Deep Renovation Implementation Management).

3.3. Business Models

4RinEU develops new business models that are fed with the technologies and the methodologies. 4RinEU business model will allow to identify the level of risk of the deep renovation process and to enable well-founded investments supported by tailor-made financial tools. All the outcomes of the project will be included in a simple cost-effectiveness rating systems, which allow the different stakeholders to evaluate risk of investment for deep renovation implementation, responsibilities, achievable performance results and relative uncertainty, as well as related costs (10-Cost-effectiveness Rating System).

4. Demo Cases and Geocluster Approach

In order to demonstrate the approaches defined within the project, the 4RinEU renovation strategy will be completely applied in three Demo-Cases that will undergo deep renovation process, from the design to the monitoring during operation. The three demo-cases owners are both private and public agencies managing an important social housing building stock, for an overall amount of around 89,600 apartments in three EU-countries (Norway, The Netherlands and Spain). Even though these agencies renovate buildings with an annual rates around 2%, usually the renovation targets are quite low and far from current best practices, mainly because lack of affordable renovation strategies compatible with the available economic resources.

Starting from the knowledge and the outcomes from the EU-funded project Ge$_2$O [3] we defined the boundaries of 6 EU geo-clusters, according to climate conditions, requirements in case of renovation and consistency of the residential building stock. In particular, in order to take into account the climate conditions, we adopted the Heating Degree Days, for the building features the amount of multi/single family houses, the main used construction materials (source: FP7 project iNSPIRE [4]) and the minimum value of thermal transmittance for new constructions and renovation.

A set simulations and analyses to tailor the 4RinEU renovation packages, according to the geo-cluster features and needs, will be carried out for a set of representative Building Archetypes selected for each geocluster. These lines of research represent 3 demo cases, pictured in Figures 1–3 and described briefly as follows:

4.1. Norway

The Norwegian demonstrator is a small multi-family house located in Haugerudsenteret, Oslo, and built in 1975. It presents two floors and 8 dwellings (average surface around 46 m^2). It is part of a complex of six buildings accounting 96 dwellings, owned by Haugerudcouncil housing estate and managed by Boligbygg.

Main renovation drivers:

- Being in line with the CO_2 emissions reduction targets of the city of Oslo
- Providing a good Indoor Air Quality
- Improving the quality of the envelope

Figure 1. Haugerudsenteret.

4.2. Netherlands

The Dutch demonstrator is a residential building in Mariënburg Soest with service and support structures for elderly people with three floors and around 65 dwellings (average surface around 50 m^2). It is owned and managed by Woonzorg and presents high primary energy consumption for heating and domestic hot water production. In fact, it was built with quite poor constructive standards and low quality.

Main renovation drivers:

- Adapting the building according to the needs of the users that are getting older
- Solving functional and safety problems
- Improving the comfort of the occupants
- Having exemplary role in the energy saving as public institution

Figure 2. Mariënburg.

4.3. Spain

The Spanish demonstrator is a multi-family building located in Lleida called the Alsamora 6. It has 4 floors and 24 dwellings (average surface around 45 m^2). Although the building is quite new, it presents high primary energy consumption. In fact, it was built during the construction bubble with poor standards and low quality. Accordingly, it represents a strategic case study for the renovation with a high replication potential for the social housing building stock in Spain. The building belongs to the Catalan Government and it is managed by AHC, Agència de l'Habitatge de Catalunya (Housing Agency of Catalonia).

Main renovation drivers:

- Reducing energy consumption to mitigate the fuel poverty issue
- Improving the comfort and the Indoor Air Quality of the occupants

High replication potential

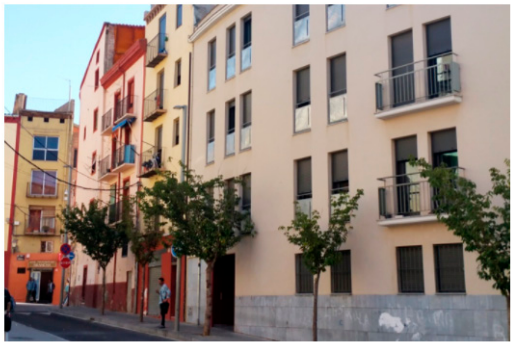

Figure 3. Alsamora.

5. Expected Impacts and Future Developments

The EU H2020 4RinEU project, coordinated by EURAC research, started the activities in October 2016 and will last for 48 months (as foreseen in the grant agreement No. 723829) in which it will develop and demonstrate technologies, methodologies and business models for fostering deep renovation across EU. The fulfilment of the expected impact will be fostered through an intensive exploitation activity, aimed at increasing the innovation capacity of the consortium with the support of a dedicated exploitation partner (R2M). The solution developments will be supported by market analysis, identification of exploitable results, draft partner agreements and multi-perspective business models to foster commercialization.

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