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New strategies towards nearly zero energy in existing buildings: the ABRACADABRA project

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Abstract

ABRACADABRA is an European Project funded by the Horizon 2020 Program, based on the assumption that substantial increase in the real estate value of the existing buildings can play a key role in the deep renovation. The project aims at demonstrating to the key stakeholders and financial investors the attractiveness of a new renovation strategy based on volumetric Add-ons and Renewable energy sources (AdoRES) intended as one (or a set of) Assistant Building unit(s) – like aside or façade additions, rooftop extensions or even an entire new building construction – that “adopt” the existing buildings (the Assisted Buildings) to achieve nearly zero energy. The creation of these AdoRES aims at reducing the initial investment allocated for the deep renovation of the existing building creating an up-grading synergy between old and new. The ABRA strategy can thus result in the implementation of a punctual densification policy that aims at fostering the investments in deep renovation of the existing built environment, driving process innovation in the construction and the real estate sector.
The paper, after outlining the main aspect of the project, focuses on a case study in Italian context, where different technological solutions and related economic impact are analysed: from a deep renovation to AdoRES strategies and different scenarios of renovation. The preliminary feasibility study and cost assessment, show the benefit given by the presented strategy in overcoming actual financial e tecnical barriers.

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Keywords: energy efficiency, deep renovation, existing buildings, volumetric additions, cost-effective solutions;

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1. Introduction

Europe's energy efficiency challenge in buildings mainly concerns the energy efficient refurbishment and investments in its existing buildings. Yet, today, only 1,2% of Europe's existing buildings is renovated every year [1]. The actual investment gap in the deep renovation sector is due to high required investments that are generally characterized by an excessively high degree of risk, by long payback times and by the general "invisibility of the energy benefit".

EU energy policies, EPBD and EED contain provisions to increase the energy performance of existing buildings and to encourage Member States to convert building stock through the development of a marketplace for cost-effective deep renovation. The development and operation of energy-efficient buildings are complex tasks that fully require the combined effort of designers in the development of the projects, qualified architects and engineers with different skills and installers and builders to deliver the building as designed and commissioned as well as building operators capable of maintaining the building in its full energy performance [2].

The building Deep Renovation (DR) refers to energy renovations process that instead of focusing on single standard actions (i.e. windows replacement, wall insulation, new generator with greater performances, etc.) involves the full economic Energy Efficiency potential of improvements by combining in one integrated strategy several necessary measures, acting upon the building envelope and plant systems.

However some barriers can be identified that act as main key gaps to develop deep energy renovation process in existing buildings:

- economic and financial barriers: high up-front costs, long pay-back times of retrofitting interventions, lack of confidence of the potential investors, scarcity and instability of available funding and split incentive;
- technical barriers: lack of standardized technical solutions or integrated solutions to comply to new and different building standards requirements on energy saving, safety/seismic risk;
- legislative barriers: insufficient incentives and the rigidity of the current regulations in the Member States notably in relation to housing and planning;
- social barriers: lack of consensus, understanding and support from the co-owners and inhabitants that often impedes the effective approval of the interventions.

The ABRACADABRA Project (Assistant Buildings' addition to Retrofit, Adopt, Cure And Develop the Actual Buildings up to zero energy, Activating a market for deep renovation) is based on the prior assumption that substantial increase in the real estate value of the existing buildings can play a key role in the deep renovation. The project aims at:

- the important reduction of the payback time of the energy retrofit interventions;
- the strengthening of the key investors' confidence;
- the increasing quality and attractiveness of the existing buildings' stock,
- the concrete market acceleration towards the Nearly Zero Energy Buildings.

Thus, the ABRACADABRA Project fits in this contest, promoting a comprehensive renovation process based on volumetric additions and building deep transformations, combined with energy renovation and the use of Renewable Energy Sources. Thus, by AdoRES we refer to one (or o set of) assistant building unit(s) like aside or façade addictions, rooftop extensions or even an entire new buildings "adopting" the existing buildings (the assisted buildings) to deeply renovate them up to nZEB.

Additions are therefore very interesting type of intervention since they instantly produce new, commercially valuable surface which could compensate the costs of energy-optimisation [3]. In this way the building DR process should be attractive to financial actors and decision-makers (financial institutions, developers, managers, householders, policy-makers, buildings owners and associations) and have an important impact also on environmental and social co-benefits.

2. The case study: a district area in Bologna

The case study presented in this paper is part of a collaboration of the University of Bologna with Emilia-Romagna Region, Bologna Municipality and ACER Bologna (local organization for social housing). The intervention area is located in a suburban area not far from the city centre and well connected through the main mobility infrastructures. More specifically, it consists of three tower blocks and a line building block all distributed along Via Torino. The neighbourhood was entirely built for social housing purposes during the ‘70s (Fig. 1).

Both blocks were built using a technique called “couffrage tunnel”, where load bearing walls are made of reinforced concrete, while internal partitions are made of bricks masonry. Large amount of thermal bridges are present, especially in correspondence with the loadbearing structure and most of surfaces are deteriorated due to climatic actions.

The design solutions of deep renovation and AdoRES have been carried on both building typologies in order to investigate technological and performance improvements.

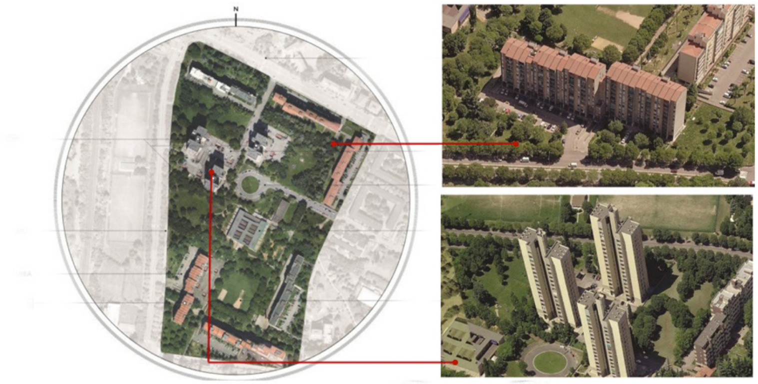

Fig. 1. Satellite view of the case study area.

3. Feasibility study: from deep renovation to ABRA scenarios

Technical and economic feasibility study has been based upon the preliminary analysis of the current state of the building and of the different components (windows, floors, walls, structure etc.). Concerning the tower block’s envelope there are two types of wall structure: a concrete structural part layered with perforated bricks in the inner part, and a curtain wall composed by perforated brick and plaster. Roof floors are composed by a concrete subfloor, concrete and plaster. The central heating plant system is realized by traditional gas boilers, a pipeline network not well insulated and emission system with radiators and convectors.

Energy simulations for the building heating demand have been performed with semi stationary models according to national standards [4,5]. Main assumption are: heating period from 15 October to 15 April; constant air change rate 0.3 h^{-1}. The mean seasonal efficiency of the heating plant was estimated to 76%.

The calculated primary energy demand of the current state of the tower building is 237 kWh/m^2year, while the line block, with similar construction technology but different dwelling position, is 286 kWh/m^2year.

The first level of intervention that has been used as reference to compare also the effect and benefits given by the volumetric addition in terms of cost analysis assessment is the Deep Renovation (DR). The DR scenario foresees the following changes for the envelope:

- substitution of the existing windows with a double glazing window frame with thermal break and overall value for window transmittance U_{window} = 1,1 W/(m^2K);
- insertion of an external insulation layer of wood fiber, 8 cm thick, for the existing walls and curtain walls reaching an overall wall transmittance value Uwall=0,238 W/(m2K);

- rooftop insulation with 12 cm wood fiber to reach a transmittance value U_{floor}=0,218 W/(m^{2}K).
- basic intervention on the plant system consisting of new heat pumps (integrated with condensing boiler) and temperature control system.

As a result, the primary energy demand reaches the level of 28 kWh/m^{2}year for the tower building and 21 kWh/m^{2}year for the line building block. In order to evaluate the energy savings and the future energy needs for the cost-benefit analysis it has been considered the current gross price for gas equal 0,769 euro/Sm^3 (IREN market price, 2016).

This scenario has been proposed in order to reach the minimum standards for energy renovation as required by the actual Italian Legislation [6] where the reference values for the thermal transmittance and the energy performance of nearly Zero Energy Building (nZEB) are set. As the area of interest is characterized by a well-established living population, a crucial aspect of the energy renovation concerns the inhabitants' disturbance which should be minimized. For this reason the proposed solution for AdoRES is based on a prefabricated technology, factory-built and assembled on site.

In order to maximize the transportable dimensions, the addition elements consist of prefabricated wooden slabs that can be assembled in a variety of type solutions to meet the different needs of the current and future inhabitants: families, couples or singles. The floor is layered with a floating floor, a wooden planking, filled with mineral wool and an insulation panel of wood fibre covered by an outer finish. These addition units could be used to implement the DR intervention as above illustrated that is assumed as a basis for all the following AdoRES scenarios:

- S1 Ground: AdoRES as additional units at the ground level in buildings with pilotis.
- S2 Rooftop: AdoRES as additional units at the rooftop level as additional building floor. This scenario includes the integration of PV plants.
- S3 Aside: AdoRES as additional units on the side of the building as extension of the existing building volume on the blind façade.
- S4 Façade: AdoRES as extension of the existing façade, including extra balconies, loggias or winter gardens.
- S5 Assistant Building: AdoRES as entire new building located in the surrounding area of the renovated one.

All these different scenarios have been tested through design experiments on the two building types, the block building and the tower building. After having conceived the possible additional living space also combined scenarios have been considered, starting from the above described 5 options for an overall number of 31 possible solutions. Fig.2 illustrates some of the possible architectural and composition outcomes given by the ABRACADABRA strategy applied to the case study in via Torino.

4. Costs and benefits

The cost-benefits analysis represents the core aspect and the innovation character of the ABRACADABRA approach to energy renovation practice. In this paper a simplified explanation is presented of the beneficial effect and impact given by the application of AdoRES when renovating a building or a district. The energy related aspects have not been detailed and described although the energy evaluation results have been included for comparing the scenarios before and after the interventions.

The preliminary assumptions for this case study are the following: 650 euros/m^2 per net surface of DR intervention of existing buildings [7]; 600 euros/m^2 for PV plant; 1.000 euros/m^2 for the construction of new buildings; 2.700 euros/m^2 for the sale price of the new building units (based on price analysis on Bologna suburbs area).

Previous analysis and energy simulations on similar case studies have shown that the average payback time of deep renovations, including also plant renewal, vary between 35 and 45 years without national incentive schemes [2]. In the specific case of via Torino the payback time of the DR has been calculated 44 years. Thus, it is clear that investments are not competitive in market terms and the payback times must be reduced.

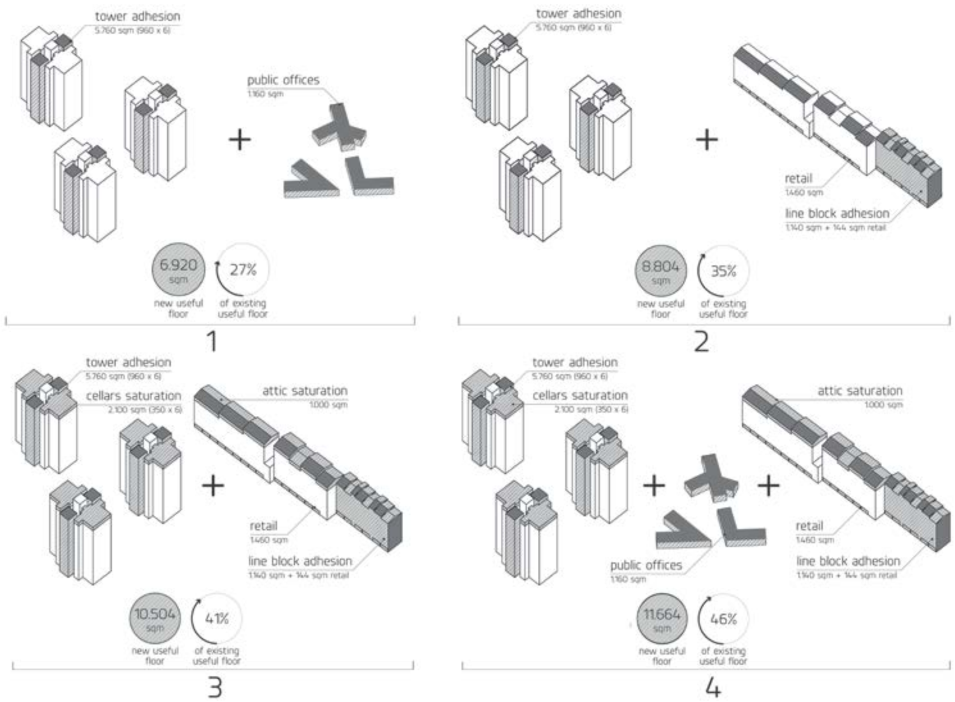

Fig. 2. This picture illustrates 4 of the 31 possible scenarios that have been analysed, showing the possible composition and architectural outcome of adding extra units to the tower and/or line building.

On a preliminary stage, calculations have been made considering a standard AdoRES addition on the rooftop, estimated around an increase of 20% of the existing living area (5.000 m^2) as allowed by the "House Plan" regulation in some Italian regions. The overall simple pay-back time, without considering any source of fiscal reduction and state incentive can be reduced down to 34 years. Applying the fiscal incentives rate, in Italy currently accounting for the 45% of energy renovation intervention (calculated only on the amount of the investment referring to the renovation and not the Add-on construction), the payback time is further reduced down to 15 years.

The key step of the economic feasibility study here conducted is based on a reverse approach. The goal is to get the required amount of addition, to further reduce the pay-back time, considering an interest rate of 5%, also without incentives schemes. At the current state the variables regarding marketable and specific conditions of the case studies are yet left undetermined. In general, parameterising with respect to the renovation costs and the estimated value of the assistant building, we aim at working on the basis of the following simplified formula:

$$PBT = \frac{C_r y + C_c x + P x}{R y} \tag{1}$$

Where:
PBT = pay back time with investment rate of 5% (year)
Cr = unit renovation costs including RES to set to nZEB the existing building (€ / m^2);
y = floor surface of existing building (m^2) ;
Cc = construction costs of the Volumetric Addition (€/m^2);
x = floor surface of additional volumes (m^2);
P = Assistant building's real estate market value (€/m^2);
R = Energy savings (€/m^2).

Using this formula it is possible to calculate the simple payback time for the above-mentioned parameters. Indeed, to increase the attractiveness of the intervention for the banks and the financial agencies, we can, i.e., decrease the return of the investment up to 8 years and calculate the necessary amount of added living area that are still necessary to cut the pay-back time, for a given a specific real estate market (Cr, Cc, P values).

As showed in Fig. 2, the additional living space can be distributed or combined in several possible scenarios, according to the different case study and circumstances becoming from an extra building floor on the rooftop up to the final scenario where an entire new building is added.

The Assistant Building may thus consist of a bonus, a complementary economic instrument for the investors (real estate investors, construction companies in conjunction with ESCO, etc.) also considering the possibility of creating a risk fund with the real estate surplus generated by the new building, that could cover the risk of arrearage for the inhabitants in paying the bills. The AdoRES may act as an attractor for private sector financing, playing an extremely important role, in a context of scarce private finance where the search for affordable up-front investments is crucial.

Considering the case study here presented, to obtain a total balance between costs and benefits, it would be necessary to build about 10.000 m^2 of net surfaces of new construction, equal to an increase of 40 % of the existing living area. As a further modelling in this framework to obtain a profit, from the masterplan a maximum of 11.700 m^2 could be built, resulting in a profit of about 2.800.000 euros. Fig.3 illustrates the results of main scenarios evaluated for the case study.

ASSUMPTIONS	CASE STUDY VIA TORINO/VIA ORTOLANI, BOLOGNA			Epi	PAY-BACK TIME
Cost of construction: 1.000 euro/mq Cost of Renovation: 650 euro/mq Real estate value: 2.700 euro/mq	CURRENT STATE	CURRENT STATE	 Area= 16.150 mq Area=8.450 mq	EPi tower= 259 kWh/mqy Epi line building= 315 kWh/mqy	-
	INTERVENTION	DEEP RENOVATION	NO ADDITION	EPi tower= 28 kWh/mqy Epi line building= 21 kWh/mqy	44 years
		SATURATION ROOFTOP	ADDED 2.020 mq	EPi tower= 28 kWh/mqy Epi line building= 21 kWh/mqy	34 years
		GROUND	ADDED 1.770 mq	EPi tower= 28 kWh/mqy Epi line building= 21 kWh/mqy	35 years
		INCREASE TOP	ADDED 3.130 mq	EPi tower= 28 kWh/mqy Epi line building= 21 kWh/mqy	29 years
		INCREASE ADHESION	ADDED 9.800 mq	EPi tower= 28 kWh/mqy Epi line building= 21 kWh/mqy	gaining 1 years investment
		COMBINATION PROJECT	ADDED 17.820 mq	EPi tower= 28 kWh/mqy Epi line building= 21 kWh/mqy	gaining 8 years investment

Fig. 3. This picture illustrates some AdoRES scenarios with corresponding energy reduction and payback time.

By the previous assumptions, for each scenario the payback time has been calculated considering the possible additional volumes, calculating the consequential revenues and the cost savings given by the energy reduction after the Deep Renovation.

Fig.4 shows in graphical terms the relationship between the calculated payback time corresponding to additional net surfaces od AdoRES. For the selected case study the necessary addition (in terms of net surface), to increase significantly the bankability of the energy renovation intervention (considering a payback time is lower than 10 years) is equal to 7.000 m^2.

Trend lines with a higher slope are expected when the difference between the cost of construction and the real estate revenues is lower than those assumed in this case study (different countries, Regions, market conditions, etc.).

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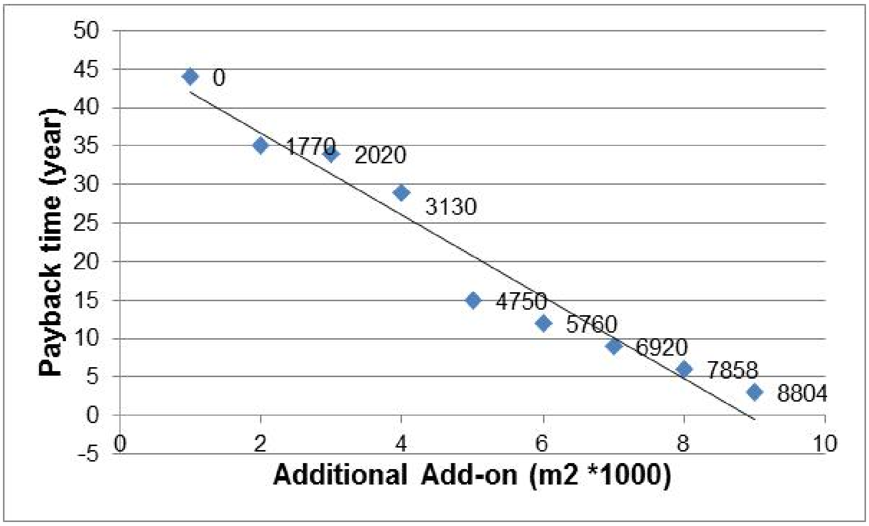

Fig. 4. Relationship between the simple payback time for each scenario and the correspondent addition in AdoRES.

5. Conclusion

Performed cost-benefit analysis in a large set of reference buildings in different contexts, including the building presented in this case study, where the hypothetic investment in AdoRES is combined with DR, showed that the potential economic gains obtained through the sale would compensate both the investment of the energy retrofit and the cost of renewable energy technologies setting to zero the energy demand of the whole building.

ABRACADABRA project will ground on feasibility studies on AdoRES already developed for representative urban compounds in more than 11 European regions and will test, expand and systematize the process in exportable models to increase the stakeholders' awareness on the technical, economic, legal and social feasibility. The different European markets in terms of value of the new units and the cost of construction already show that the potential of the strategy has different impacts among the different Member States, showing a great investor appealing for those areas where the real estate market is still healthy.

The implementation of volumetric bonus as compensation measures for energy renovation still represents a challenge when considering the current regulatory and normative framework, since this strategy is not always admitted and a series of barriers must be considered. The main threats to be overcome are also connected with the environmental and social aspects due to the planned interventions: potential loss of permeable soil due to the increase of parking areas, increase of the population in the urban area and possible psychological reactions to the new social density by the existing population.

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