TEMA
Technologies Engineering Materials Architecture
e-ISSN 2421-4574
Vol. 4, No. 3 - Special Issue (2018)

Retrofit through Add-ons: the ABRACADABRA strategy as an opportunity for the energy renovation of private-owned and public buildings

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Highlights

ABRACADABRA is an H2020 project that aims to activate a market for the deep renovation of existing buildings through volumetric additions (Add-ons) reducing the payback time of the investment. Numerous pilot case studies have been used to test the efficacy of the strategy. One of the most challenging sectors as the social housing has been explored to verify through a process based on the cost-effectiveness analysis, whether a retrofit strategy combining add-ons and densification could help to boost the renovation of the public and private owned housing stock.

Abstract

The EU environmental and energy policies are promoting energy efficiency retrofit actions, in spite of the fact that the renovation rate in the construction sector is very low. The ABRACADABRA project aims to activate a deep renovation market through volumetric additions (add-ons), including one of the most challenging sectors, the social housing. In order to demonstrate how the densification action could be an effective solution to promote energy efficiency interventions and new business models with the scope to shorten the payback time of renovation investments (both at building and urban scale), four different buildings in different urban contexts have been analysed. The simulation made on these case studies is divided in three steps: an architectural feasibility study, an energy saving analysis and a payback time calculation; in this last phase of the study the financial assumptions are fundamental. The real estate values like the sale and the rental rate, as well as the social values were well-thought-out and combined in order to find the best opportunity for profits and the shortest payback time. Moreover, additional issues were taken into account regarding the regulatory aspects and the technical feasibility barriers for this type of approach. Implementing this strategy means to add new units on the rooftop or on the side of an existing building, and this might face obstacles, such as urban regulation restrictions and the consensus among tenants or owners. To overcome these mainly social obstacles, the project promotes new policy recommendations that public authorities could adopt and approve and also counterbalanced measures to help tenants/owners accept and embrace the ABRA strategy.

Keywords

Energy renovation, Social housing, residential buildings, Payback time reduction, Renovation market, Add-ons, Densification

1. INTRODUCTION

It is widely acknowledged that the residential stock in Europe is one of the most energy consuming sectors. Most of the existing buildings have been built between the '50s and the '70s without regulations about building performances and energy savings. These buildings, constructed during the economic boom

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TEMA
Technologies Engineering Materials Architecture
e-ISSN 2421-4574
Vol. 4, No. 3 - Special Issue (2018)

show poor thermal performance and high fuel consumption. [1]

The EU is trying to reverse this trend by promoting energy retrofit actions on the existing buildings, notably through the implementation of the Energy Efficiency Directive [2] and the Energy Performance of Building Directive [3]. Despite these efforts, deep renovation actions cover only about 1% of the construction sector activities [4]. Europe's energy efficiency challenge in buildings mainly concerns the energy efficient refurbishment and investments in its existing buildings stock [5]. With the expression Deep Renovation is meant as an ensemble of measures that capture the full potential of improvements in energy efficiency, all integrated in a strategy acting upon the building's envelope and HVAC system [6]. According to the definition provided by the Global Building Performance Net- work (GBPN), the yearly primary energy consumption after Deep Renovation, should be less than 60kWh/m2 [7]. There is clearly a lack of investments from the potential investors in deep renovation activities. This is due mostly to the high up-front costs, long payback times and legislative barriers.

The European H2020 project ABRACADABRA has identified these key obstacles and aims to overcome them, based on the assumption that an increase of the real estate value of the renovated building could trigger deeper renovation interventions. ABRACADABRA strategy is based on volumetric Add-ons and Renewable Energy Sources (i.e. AdoRES), such as aside or façade additions, rooftop extensions or even an entire new building construction (the Assisted Buildings), that "adopt" the existing buildings to achieve nearly zero energy and to activate a new real estate market decreasing payback times. In this paper, we will describe how this strategy is applied in different sectors and scales: social housing, public and private owned buildings, and an entire urban compound. The dissertation will show the results obtained in a case study of Social housing in Reggio Emilia area, a Student House in Athens, and the Corticella compound in Bologna, demonstrating how the AdoRES can increase the attractiveness of deep renovation market reducing payback times, by raising their real estate value and adding new units [8].

2. CHALLENGES AND BARRIERS OF ENERGY RETROFIT IN RESIDENTIAL SECTOR

2.1. COMMON CHALLENGES TO THE SOCIAL HOUSING AND PUBLIC BUILDINGS

Literature to explain the low renovation rate in the housing sector is abundant.

The financial aspects, such as the high upfront costs, long payback times, the lack, instability or complexity of available funding or fiscal incentives are often considered as the main barriers to renovation. But they are not the only ones. Despite the acknowledged non-energy related benefits of energy efficiency renovation – such as health and comfort, architectural and aesthetic improvements, end-users might not recognise the benefits of an energy efficiency renovation. They might also mistrust new technologies and constructions professionals or simply might not be aware of the possible retrofit choices. Hence, it is important to raise awareness about all the benefits of an energy efficiency renovation, unbiased and impartial technical and financial advice and support. On top of that, regulatory factors and administrative procedures can further hinder energy renovation. This includes urban planning rules, constructions permit procedures, but also rules linked to property and housing law, such as decision-making rules in multi-apartment buildings, contractual obligations towards the tenants (including rent increase limitation and relocation obligations).
Such barriers, to name only few, are considered as main factor of the low renovation rate in the entire housing sector, although at a different level (depending on the sector). Overcoming them has become a political priority in order to foster a more energy efficient European building stock.

2.2. SOCIAL HOUSING AND PUBLIC BUILDINGS' SPECIFIC CHALLENGES

Beyond or in addition to the challenges mentioned before, energy retrofit in the social housing context faces additional challenges. Therefore, it might be considered as the most difficult sector for energy renovation actions. This is notably due to the split-incentive issues (which also occurs in the private rented sector), as well as the limited margin of manoeuvre regarding rent increase. Often the owner of the building is a local authority and the tenants' monthly overhead expenses include a social rent and utility bills. Furthermore, the contractual relationship between owners and tenants and the fact that the landlords need to relocate their tenants during the construction period could further hinder deep renovation plans. This is also valid for the private sector, but there the tenants' turnover might allow for more flexibility. In addition, rent or bills arrears that might occur in social buildings are a burden for the owners and energy companies. Taking these challenges into account, it is necessary to promote a cultural change among tenants, by informing them about the benefits of a low energy consumption house and by promoting

e-ISSN 2421-4574
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energy-efficient behaviour. Poor knowledge about behavioural adaptations of occupants after an energy renovation, can create rebound effects and offset the expected monetary and energy savings of an energy efficient house [9].

ABRACADABRA strategy promotes a user-orientated renovation to overcome all these challenges, providing counterbalancing measures such as adding extra-room, a balcony or sunspaces (facade addition) to the existing units. From a social point of view, it could be an opportunity to reduce social exclusion and a general renovation of the urban area.

Finally, when applying the business models based on the ABRACADABRA calculation tool, the payback periods for the energy retrofit in a social housing building results in very long payback periods, an outcome mainly due to the low rent rates in this specific sector.

Thus, the specific challenges that energy retrofit has to overcome in public buildings are linked to property regime. It is, in fact, necessary that public bodies start the action and in some cases is very difficult to have a short payback time because they have particular business model to capitalize the additions. It also true that, in general, municipalities and public bodies can burden long-term investments.

3. METHODOLOGY

The research study was carried out f with the following steps:

- An architectural feasibility study of the possible Add-ons for the building;
- The energy consumption analysis before and after the deep renovation using a Simplified Energy Model (SEM);
- Calculation of the renovation and construction costs;
- Payback time calculation for different scenarios.

The feasibility study needs to individualise the workable addition within the ones defined by the ABRA strategy:

Fig. 1 illustrates the different renovation scenarios that consider a densification at the scale of the building. Starting from the standard energy renovation of the original building, which is also assumed as a constant in all the incremental scenarios, other five options are taken into account.

This feasibility simulation is the crucial starting point of the ABRA strategy since it is very rare that all the AdoRES can be applied to one single case study (due to regulatory or architectural issues). Also, in order to be a successful intervention it is necessary to know how much surface can be added.

The renovation measures include actions on the envelope (external coating,

TEMA Technologies Engineering Materials Architecture
e-ISSN 2421-4574
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windows replacement) and the HVAC system. The necessary measures are identified by targets in order to maximize energy savings. (i.e. specific U-values for each opaque surface).

Subsequently the energy consumption analysis is conducted using a Simplified Energy Model (SEM). The calculation is conducted in stationary mode according to EN ISO 13790 [10] and ISO EN 52016-1 [11].

The main inputs needed for calculation are the principal climate and energetic data (geometric values of the building, heat sources, transmission and ventilation properties, set points etc.).

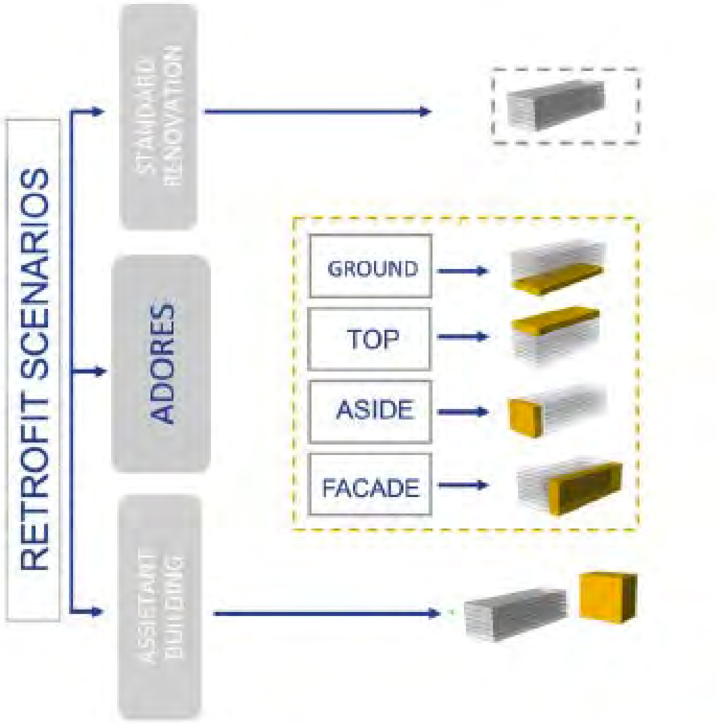

Figure 1. Renovation scenarios.

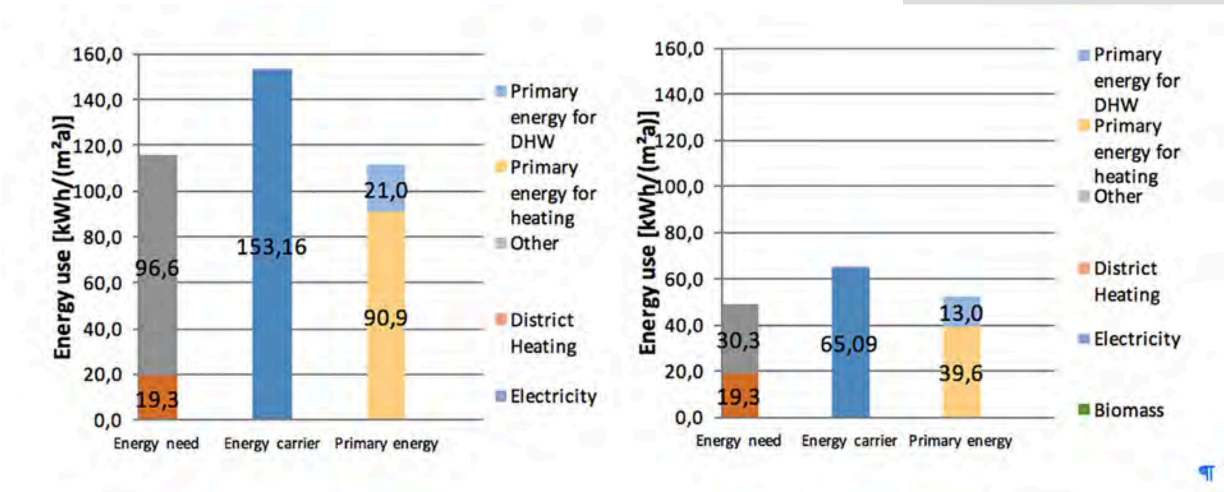

Figure 2. Example of energy use BEFORE and AFTER the deep renovation.

As a result of the simulation the SEM gives as outputs monthly and annual energy needs of the building before and after the deep renovation. All energy parameters are calculated as monthly mean values and then used to calculate seasonal values.

Those results are fundamental for the economic evaluation of the deep renovation; in fact, since there is a standard to reach, every case study will have different parametric renovation cost (€/m^2) depending on the current state of the building.

Regarding the construction cost, it is necessary to conduct the feasibility study to have an idea of the intervention, and to agree on a standard construction.

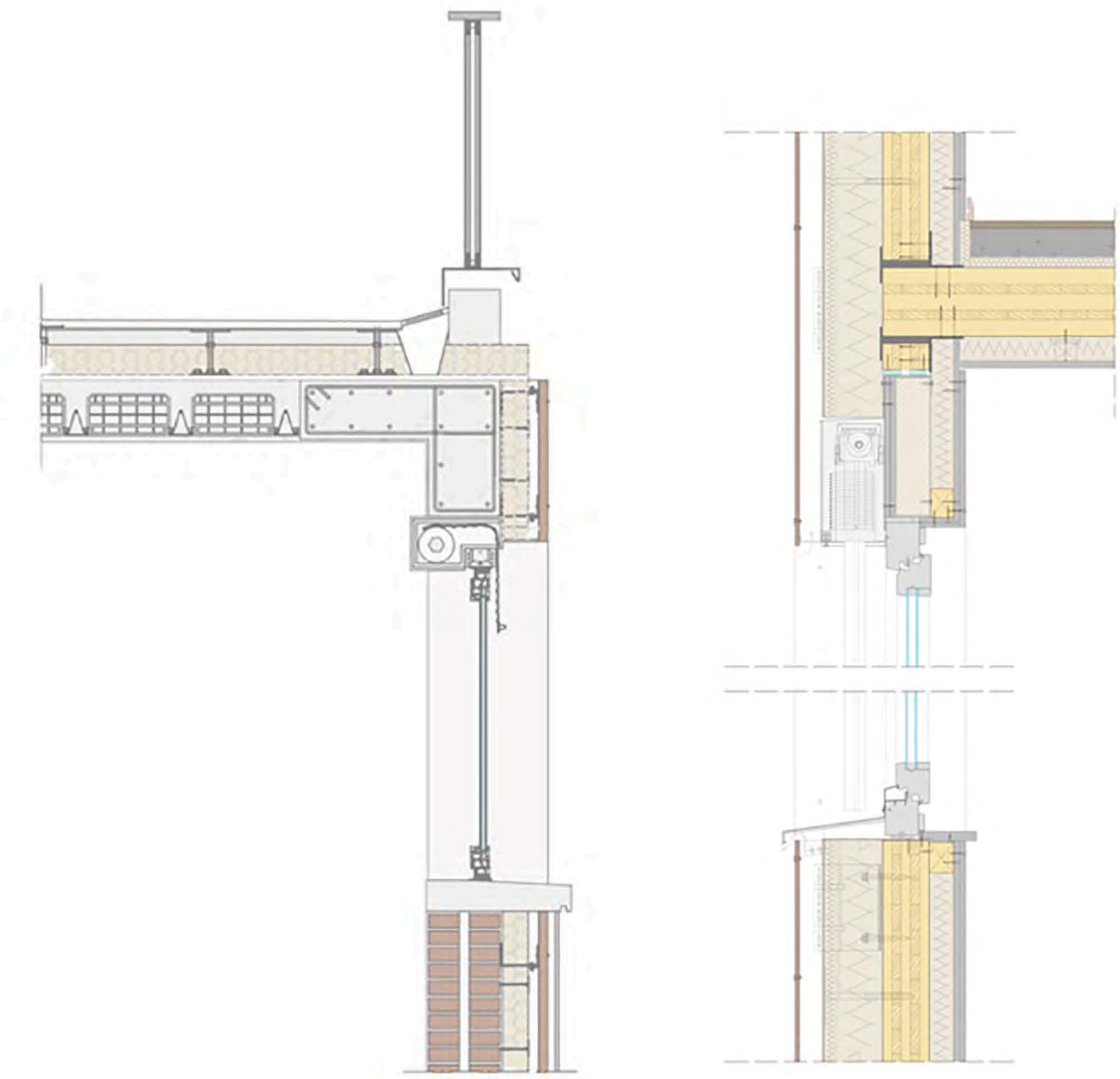

Figure 3. (On left) Example of renovation packages.
Figure 4. (On right) Example of construction packages.

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The Add-ons are built with timber panel for opaque surfaces and aluminium triple glaze windows filled with argon in order to reach a zero energy target with the use of PV panels and heat pump for heating and cooling. Renewable Energy Sources (RES) like photovoltaic panels are also installed in the existing building to reach the nZEB target.

Renovation and construction costs [12] and energy consumption are the principal factors in the calculation of the payback time. The negative cash flow that is linked to these costs is balanced by the energy savings and by the profit realised from selling or renting the added units. In the case of a sale transaction, we simulated that all the new dwellings would be sold in the first two years after the end of the construction (this is a hypothesis based on the state of the market). This cost-effectiveness comparison allows for immediate identification of the most relevant scenario for the investors and stakeholders.

4. CASE STUDIES

Several case studies have been used to test the retrofit action trough Add-ons or ADORES, as named in the ABRACADABRA project. The first case shown in this study is owned by ACER RE (a social housing corporation), in Reggio Emilia, Emilia Romagna, Italy.

4.1. SOCIAL HOUSING: VIALE MAGENTA, REGGIO EMILIA

The regulatory framework imposes to comply with the "social prices" also in case of volumetric additions making more challenging the possibility to

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e-ISSN 2421-4574
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COST ESTIMATION

PACKAGES	€/ UoM	DEEP RENOVATION COST FOR THE SCENARIOS: DEEP RENOVATION			TOP			ASIDE			FACADE			GROUND FLOOR			ASSISTANT BUILDING		
		Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot
		SQM	SQM		SQM	SQM		SQM	SQM		SQM	SQM		SQM	SQM		SQM	SQM	
1.1 THERMAL ENVELOPE																			
1.1.1 Structure	2,86 €			- €			- €			- €			- €			- €			- €
1.1.2 Facade	150,00 €		685,7	102.847,50 €		685,7	102.847,50 €		562,15	84.322,50 €		405,7	60.847,50 €		685,7	102.847,50 €		685,7	102.847,50 €
1.1.3 Roof	42,00 €	280,0		11.760,00 €	-65,0		2.730,00 €	280,0		11.760,00 €	280,0		11.760,00 €	280,0		11.760,00 €	280,0		11.760,00 €
1.1.4 Floors	23,00 €	1442,0		33.166,00 €	1442,0		33.166,00 €	1442,0		33.166,00 €	1442,0		33.166,00 €	0,0		- €	1442,0		33.166,00 €
1.1.5 Openings	220,00 €		121,4	26.697,0 €		121,4	26.697,00 €		121,4	26.697,00 €		54,7	12.028,50 €		121,4	26.697,00 €		121,4	26.697,00 €
1.2 INSTALLATIONS		Unit			Unit			Unit			Unit			Unit			Unit		
1.2.1 RES	284,00 €			- €			- €			- €			- €			- €			- €
1.2.2 HVAC	20.000,00 €	12		240.000,00 €	12		240.000,00 €	12		240.000,00 €	12		240.000,00 €			- €	1		20.000,00 €
1.2.3 Electrical system	50,00 €	12		600,00 €	12		600,00 €	12		600,00 €	12		600,00 €			- €	50		2.500,00 €
		€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot
Total		402,98 €	1030	415.070,5 €	388,91 €	1030	400.580,5 €	385,00 €	1030	396.545,5 €	347,96 €	1030	358.402,0 €	137,19 €	1030	141.304,5 €	191,23 €	1030	196.970,5 €
		CONSTRUCTION COST FOR THE SCENARIOS			TOP			ASIDE			FACADE						ASSISTANT BUILDING		
	€/ UoM				Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot	Unit of Measure		€tot
					SQM	SQM		SQM	SQM		SQM	SQM		SQM	SQM		SQM	SQM	
2.1 ADORES STRUCTURE																			
2.1.1 AdoRes Structure	800,00 €				345,0	0,0	276.000,00 €	0,0		- €	200,0	0,0	160.000,00 €	0,0	0,0	- €	0,00	0,00	- €
2.2 ADORES THERMAL ENVELOPE																			
2.2.1 AdoRes Facade	150,00 €					40,7	6.111,00 €		57,5	8.622,00 €		851,2	127.680,00 €		0,0	- €		0,00	- €
2.2.2. AdoRes Roof	42,00 €				336,00		14.112,00 €	44,3		1.859,76 €	84,0		3.528,00 €			- €	0,00		- €
2.2.3 AdoRes Floors	23,00 €						- €	44,3		1.018,44 €	84,0		1.932,00 €	0,0		- €	0,00		- €
2.2.4 AdoRes Openings	220,00 €					25,4	5.588,00 €		84	18.480,00 €		187,2	41.184,00 €		0	- €		0,00	- €
2.3 ADORES INSTALLATIONS					Unit			Unit			Unit			Unit			Unit		
2.3.1 AdoRes RES	284,00 €				336		95.424,00 €	336		95.424,00 €			- €			- €	0		- €
2.3.2 AdoRes HVAC	17.201,97 €				4		68.807,88 €	0		- €	0		- €			- €	2		34.403,94 €
2.3.3 AdoRes Electrical system	50,00 €				4		200,00 €	0		- €	0		- €			- €	20		1.000,00 €
2.4 Yard general costs	15%						69.936,43 €			18.810,63 €			50.148,60 €			- €			5.310,59 €
					€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot
Total					1.554,14 €	345	536.179,31 €	542,16 €	266,0	144.214,83 €	659,47 €	583	384.472,60 €	0,0	0	- €	0,0	0	40.714,53 €
		DEEP RENOVATION AND ADORES CONSTRUCTION COST FOR THE BUILDING																	
					€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot	€/ SQM	Cond. Area, m²	€tot
Total					681,28 €	€ 1.375,0	€ 936.759,8	417,25 €	€ 1.296,0	€ 540.760,3	460,55 €	€ 1.613,0	€ 742.874,6	137,19 €	€ 1.030,0	€ 141.304,5	230,76 €	€ 1.030,0	€ 237.685,0

Figure 5. Cost estimation summary.

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e-ISSN 2421-4574
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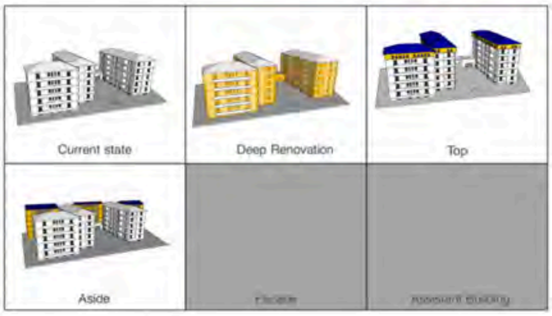
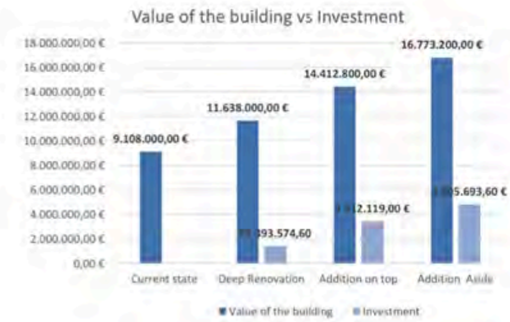
shorten the payback time. The only exception is the construction of a stand-alone assistant building, in which case they could sell or rent at market prices. The case is set in Reggio Emilia, it is a concrete skeleton with brick walls old building, with a common courtyard. The property regime is mixed (owner and tenants from ACER Reggio Emilia). To prove the technical and architectural feasibility of the Add-ons, the building and the additions have been 3D modelled.

As the feasibility table shows, in this case, it is not possible to add a facade addition or an assistant building. Therefore, the only scenarios that can be taken into account to calculate the payback times are the top addition and the aside addition. Compared with the results of a deep renovation which has a cost of € 1.393.574,60, the addition on top has a construction cost of € 3.412.119, while the Aside addition has a cost of € 4.805.693,60 (including deep renovation measures). This higher up-front cost has a return on investment both in terms of real estate value of the building and in terms of payback times because of the high number of added units. If we consider the possibility of selling new added units at market prices, the incomes would reduce the PBT (Payback Time) very quickly (only 2 years). In addition, two renting scenarios were also simulated: one with rent at the market value (8,8 €/m^2 per month) and one with the regulated social rent (5 €/m^2 per month).



Real estate value	**1.800,00 €/m^2**
Real estate value (add-ons)	**2.800,00 €/m^2**
Monthly rent for new units	**8,80 €/m^2**
Social monthly rent for new units	**5,00 €/m^2**



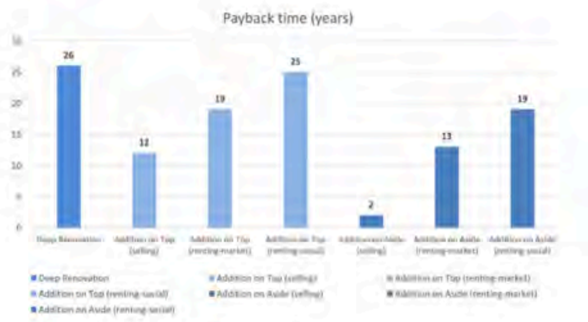


Figure 6. From left to right, clockwise: 3D model of the ADORES, economic data used for simulations, Comparison between value of the building and investment for the scenarios, comparison of the payback time in the different scenarios.

e-ISSN 2421-4574
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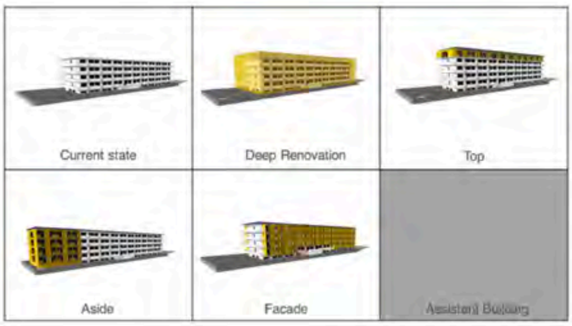
As the figures demonstrate, in this case the optimal scenario is that which maximizes the densification rate (aside addition).

4.2. PUBLIC BUILDING: ZOGRAFOU, ATHENS

This specific case study examined in this paper is the student house in Zografou, Athens. The first part of the process is the same of the other buildings, but the payback time has to be calculated with different business models. The student house has 138 bedrooms and it is property of the University of Athens.

From the architectural feasibility study we can see how, in this case, it is possible to add a rooftop extension and an aside addition to increase the number of bedrooms to rent. A deep renovation intervention would have a cost of 658.103€ with a payback time of 35 years. To evaluate the most suitable option both of the add-ons were considered, with different values of monthly rent based on the possible inhabitants and the specific market (i.e. private, visiting professors or students) and then the PBT has been calculated. From a comparison between the table and the graphs above it is obvious that the addition on Aside is the best option for the building, no matter which value of the rent we assume.

Moreover, there is a major increase of the value of the building with a minor investment. This case is an example of a valid implementation of the renting business model.



Real estate value	**1.100,00 €/m²**
Monthly rent Value (1)	**10 €/m²**
Monthly rent Value (2)	**8 €/m²**
Monthly rent Value (3)	**6 €/m²**

Figure 7. Add-ons Feasibility tables in different cases.

4.3. PRIVATE RESIDENTIAL BUILDINGS CASE STUDIES: THE CORTICELLA URBAN COMPOUND

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Corticella is an urban compound in the northern suburb of Bologna. The research regarded 21 private owned buildings that are served by a cogeneration system, built between 1970-1980 for a total of about 100.000 m^2. The 21 buildings are mostly block building with 4 towers, with different average dimension. To study the feasibility on this amount of building, each one was 3D modelled and all the surfaces (opaque and transparent, vertical and horizontal) were counted in order to have a the most accurate calculation of the renovation costs.

Then the ABRA strategy (and the process previously explained in this paper) was applied on all the building, but in this paper we will show the result of just one block building and how this developed strategy effects all the compound. In figure 8 we can see the architectural feasibility of the building taken as an example. It shows that the possible additions are: Top, Aside, Façade and Assistant Building. To compare these scenarios a cost-effectiveness analysis

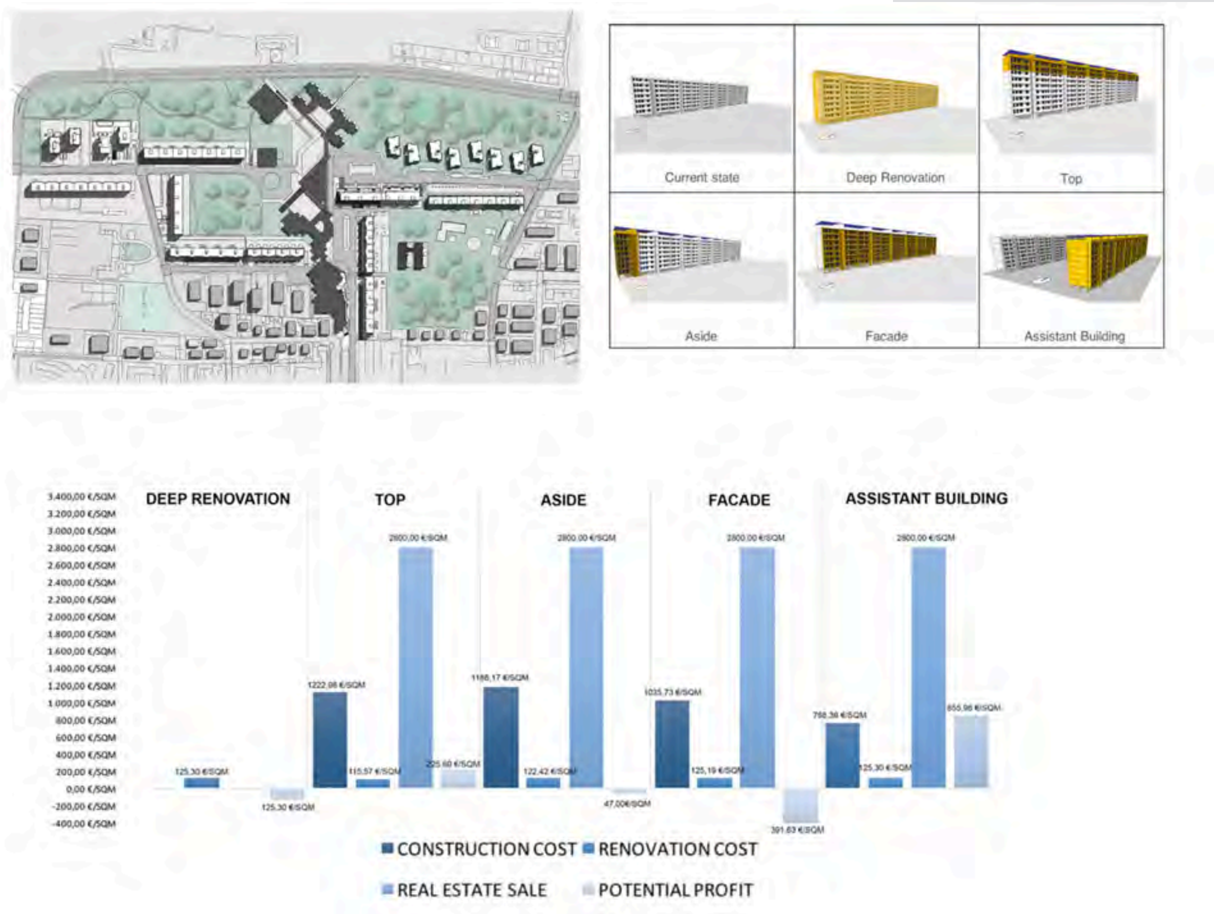

Figure 8. From left to right, clockwise: The Corticella compound, 3D model of the ADORES for one building,, Comparison between costs and profit of the different scenarios.

has been done, with costs and profit parameterized on the gross area of the building (€/m^2).

The graph shows this comparison and we can see that the most profitable scenario is the “assistant building” with a potential profit of 856 €/m^2.

Having applied the same analysis on all the buildings we were able to have an overview of the total profit and payback times for the entire compound. For that reason, after having identified the most profitable and sustainable scenario for each building, the research moved its focus on the urban scale. Once chosen the optimal scenario for each building, we could see how the densification action has a payback time of 2 years and altogether the impact of the interventions reaches a potential profit of € 38.837.733,00 [13]. Having such a results made us try to apply the strategy also on the central blocks, that has public destined buildings.

The central block includes public services like supermarket, schools and library. From figure 8 we see how it is possible to have all the public buildings renovated. This research wants to include also an experimentation of a densification on public buildings to increase this profit and to activate the market of energy retrofit also in this sector.

The hypothesis of the densification of the central block considers three towers, a top addition with a residential destination and a L-shaped building with both residential and commercial activities. Simulating to sell the new units at market prices we will have an initial profit of € 12.500.000,00.

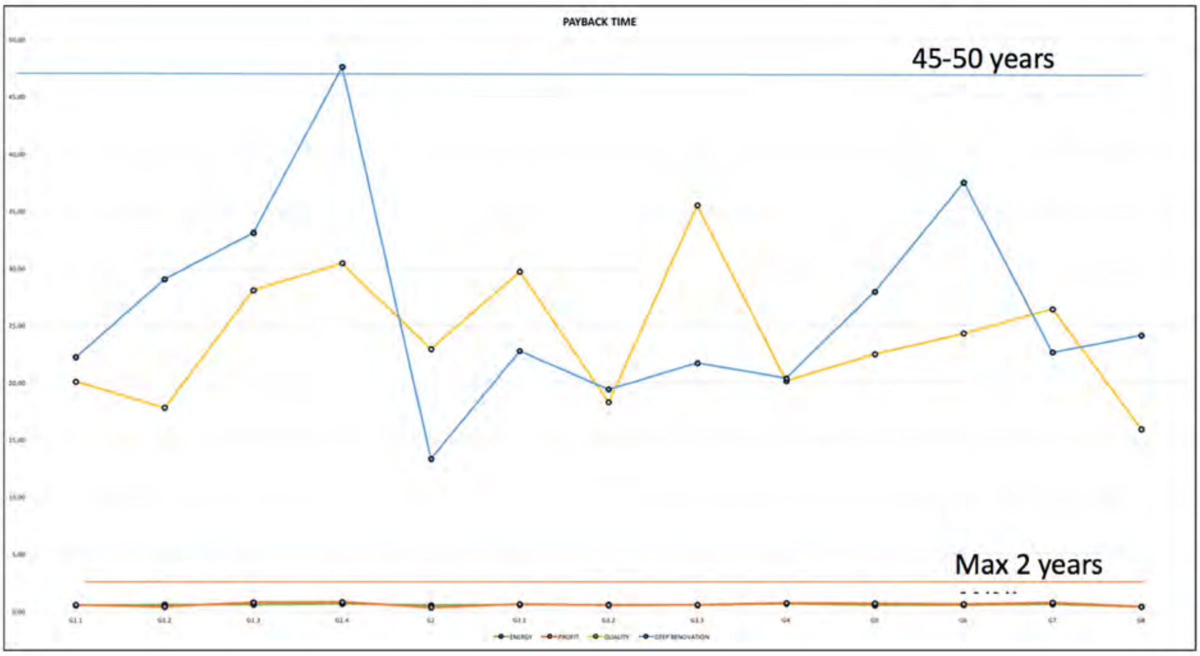

Figure 9. Payback times for each building, the blue line indicates the payback time for a simple deep renovation, the orange one shows how the densification decrease it at max 2 years.

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e-ISSN 2421-4574
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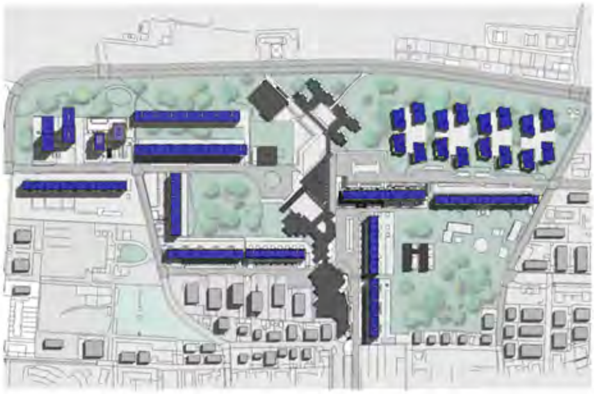
Then we considered the costs for the deep renovation of the original buildings, for the green roofs and for the PV system.

Thanks to this new layout, with a profit of €10.400.00,00, it is also possible to restore almost the 90% of the permeable soil, making the densification a sustainable solution. [14]



Real estate value Current State	**2.200,00 €/m²**
Real estate value Addition	**2.800,00 €/ m²**

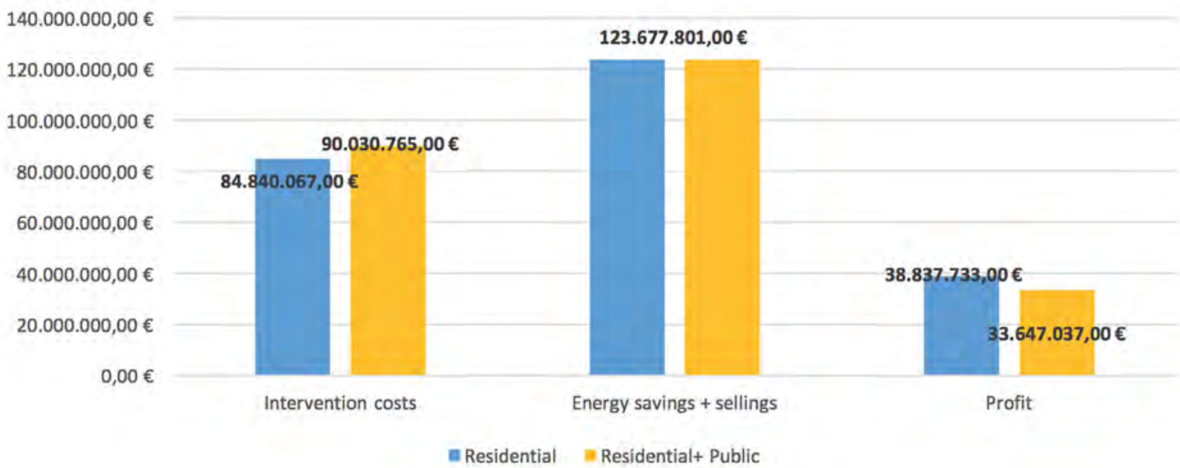


Figure 10: From left to right, clockwise: 3D model of the ADORES, economic data used for simulations, Comparison between costs and profits.

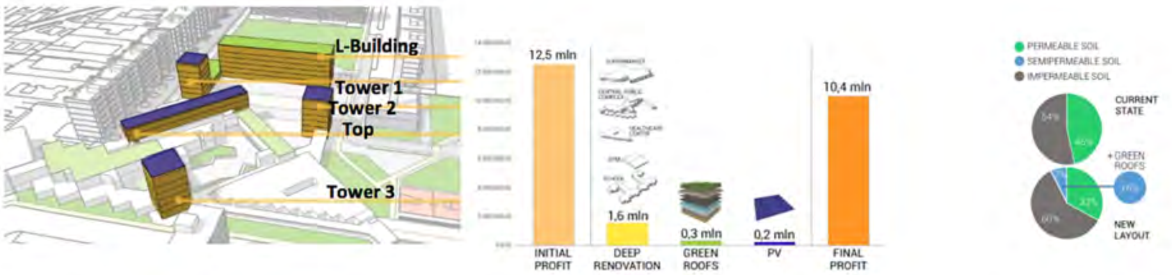


Figure 11:From left to right: possible densification on the central block, costs and profit, permeable soil after the intervention.

5. CONCLUSIONS

Different scenarios have been tested in order to investigate the feasibility of the interventions and it has been demonstrated that the cost-benefit evaluation is a valid method to identify the optimal scenario; in the totality of the investigated cases, the payback times are significantly reduced thanks to the Add-ons' strategy. Implementing a policy based on the Add-ons' strategy, would allow the addition of new construction surfaces without reducing the land permeability, and could be a strategy for the urban and architectural renovation. In this framework though, there are some issues to be solved. Some are specific to the social housing sector, other might be more general and linked to the "split incentive dilemma" in the renting market. In the social housing sector, since rent increase possibilities are limited, other solutions might be used, such as the implementation of the "Golden Rule" principle where the potential rent increase is compensated by lower energy bills which, put together, do not exceed the total of the previous rent and pre-renovation energy costs. Another solution is to create a new business model where the Social housing associations could act like ESCOs.

As the case of the Corticella compound has illustrated, densification could be even more sustainable if considered at the urban level: here, in fact, the densification could be a strategy to boost the energy retrofitting actions, the urban renovation of the outdoor spaces, while creating new public services/ utilities and responding to the need of new houses without consumption of new soil.

Altogether, this paper shows us that Add-ons solutions can help to boost deep energy efficiency renovation by creating additional real estate values, rental incomes and by reducing the pay-back period. The impact of those solutions will however vary according to the local circumstances and the market(s) considered. The estimated payback time will moderately or considerably differ if the property renovated and its extension are to be sold or rented, or if the rents are subject to market restrictions – as it is the case of the social housing sector, - but also in part of the private housing sector with controlled rent, or if in the local housing market demands and related rental and sales are extremely high or very low.

ACKNOWLEDGEMENTS

The paper here presented is part of the project ABRACADABRA, funded by the EU under the program H2020, G. A. n. 696126.

TEMA Technologies Engineering Materials Architecture
e-ISSN 2421-4574
Vol. 4, No. 3 - Special Issue (2018)

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