SUSTAINABILITY IN EVOLVING CITIES THROUGH DENSIFICATION: THE ABRACADABRA STRATEGY FOR BALANCING ENERGY AND COSTS OF DEEP RENOVATION PROCESSES

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ABSTRACT

The European project ABRACADABRA is based on the idea that an appropriate densification strategy in urban environments could be an opportunity to activate a market for urban regeneration and deep energy renovation; as a matter of fact, the proposed renovation is based on volumetric add-ons and renewables intended as so called "assistant buildings' unit(s) (i.e. aside or rooftop extensions or entire new constructions) that "adopt" the existing buildings to achieve a synergy between old and new to generate a nearly zero energy balance. This results in a punctual densification policy that aims at fostering investments, while potentially repairing the modern city form. In this context, the project promotes a sort of legislative and market "earthquake" accelerating a potential revolution in the existing urban settings. The effectiveness of this strategy has been assessed in more than 70 case studies, also outside the EU, in order to verify its scalability and considering other non-energy related benefits. This paper illustrates specific studies in NYC and Athens (Greece) that combine the global drivers of energy reduction with specific local needs. Results demonstrate how the add-ons' strategy may help preserving soil consumption while providing an extraordinary opportunity to enhance urban resiliency by challenging local emergencies.

Keywords: de-carbonization, nearly zero energy buildings, densification, add-ons, safe and resilient cities

INTRODUCTION

Today, more than two thirds of the European population lives in cities and their surrounding urban areas (EU Report, Cities of tomorrow, 2011, EUROSTAT, 2018), which are responsible for the 80% of the overall energy consumptions in Europe (EU Report, World and European Sustainable Cities, 2010, EUROSTAT, 2018). It is widely acknowledged that Europe's energy efficiency challenge in buildings mainly concerns the energy efficient refurbishment and investments in its existing buildings. In fact, three quarters of the buildings standing today, including the residential stock, are expected to remain in use in 2050. EU energy policies, EPBD and EED contain provisions to increase the energy performance of existing buildings and to encourage Member States (MS) to convert building stock through the development of a marketplace for cost-effective deep renovation. However, today, only about 1% of Europe's existing buildings is renovated every year. As a consequence, new ways of living and innovative strategies are needed to attract citizens, investors and main stakeholders in this market.

The project ABRACADABRA is based on the prior assumption that the substantial increase in the real estate value of existing buildings can play a key role in the deep energy renovation. The non-energy related factors to increase this value are (iii): i) Creation of new surfaces (add-ons), in order to counterbalance the economic investments for energy saving measures; ii) Increase of architectural quality; iii) Landscaping upgrading. As a matter of fact, the strategy promoted by the project has addressed another important critical point: the urban sprawl.

Actually, through adding residential space to existing buildings, i.e. activating and conducting an urban densification, in many cases it is also possible to limit land consumption and protect the green spaces around cities. This aspect is extremely important because cities and residential buildings are both facing two challenges: how to find the land to build affordable housing units and how to accelerate the renovation of existing homes. The aim of the project is to formulate common solutions to those challenges, testing and implementing measures to increase the urban density by adding habitable space to existing buildings. Once capitalized this value by selling or renting the extra surface, the created income can help to finance the energy renovation of the entire building. Indeed, it can also help to increase the architectural quality and reshape the urban landscape.

Specific studies presented in this paper on a NYC urban area and in Kallithea urban area in Athens have been conducted to adapt the strategy and combine the global drivers of energy consumption reduction, urban regeneration, elimination of urban expansion with also the local need of combating flood emergency in the case of NYC.

THE ABRACADABRA STRATEGY AND URBAN DENSIFICATION

The project ABRACADABRA aims at proving the effectiveness and attractiveness of a new renovation strategy based on volumetric Additions (Add-ons) and Renewable Energy Sources (RES) for the creation of *AdoRES*, intended as one or a set of service units (Assistant Building units) applied to existing buildings, to achieve the nearly zero energy target. The technical feasibility of *AdoRES* at the building scale has been based on the categorization of different possible scenarios, starting from the deep energy renovation assumed as "the entry level" for any following renovation through the Add-ons, which are classified in: ground, top, aside, façade and Assistant Building (Fig. 1).

(a)

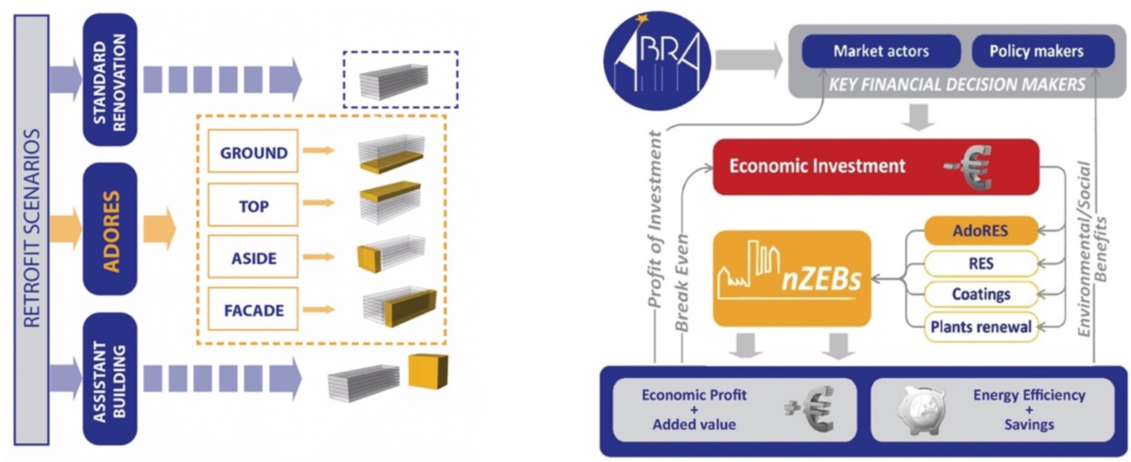


Figure 1. Schemes representing the strategy proposed by the ABRACADABRA project: (a) Different scenarios of intervention; (b) Strategy to activate a self-financing cycle to achieve nZEBs in existing buildings through AdoRES (© 2019, ABRACADABRA Publishable Report H2020).

This strategy, if adopted at the city scale, can lead to the implementation of a punctual densification policy within the built still-transformable parts and areas of cities. In this context, the objective of the project is to provoke a legislative and market change accelerating the revolution towards nearly Zero Energy in existing buildings. As a matter of fact, the research project, although initially designed to address the market for private residential buildings (which represent the vast majority of the urban building stock) at the scale of the individual building project, has also effectively addressed another current highly critical issue: urban expansion. In fact, the activation of urban densification can help reducing urban expansion protecting green spaces around cities. Many urban planners and scholars have been recognizing the advantages in intensifying the density of urban settlements, thus considering the compact city model as more sustainable in terms of energy consumption and pollution than suburbs (Breheny M. 1995; Newman and Kenworthy, 1999). Indeed, denser cities optimize energy and transport flows by using existing infrastructures, intensifying public transport and reduce pollution (Newman P., Kenworthy J., 1989)

By allowing the addition of new surfaces without increasing soil sealing, the implementation and diffusion of this approach could be therefore a valid strategy for both architectural and urban renewal.

CASE STUDIES

More than 70 case studies have been analyzed to demonstrate the feasibility of the scenarios in different EU contexts. From the obtained results, it can be observed that the real estate value of the building is always far higher than the value of the corresponding deep renovated building and the payback-time of investments may drop down to zero in the majority of cases. Furthermore, performed cost-benefit analysis in the considered reference buildings, where the hypothetic investment in add-ons is combined with the deep renovation, showed that the potential economic gains obtained through the sale would actually 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.

To test the validity of this strategy in this paper, simulations have been conducted on two cases in different urban contexts. The first one, Case A is a block of buildings in Red Hook (Brooklyn, NY). Red Hook area (Fig. 2) has been selected as part of the High-Risk Flood areas and one of the neighborhoods hardest hit by Hurricane Sandy and (NYC Housing Recovery, OneNYC). The second case is a typical Athenian urban dense plot with blocks of apartments in the area of Kallithea in Athens Metropolitan Area, Greece. This area has been selected due to its importance as it is one of the largest and more dense municipalities in the Attica region, connecting the city center with the sea front.

METHODOLOGY, SIMULATED SCENARIOS AND FINDINGS

Regarding Case A, the hypothesized interventions of flood-proofing and deep energy renovation are:

- Wet flood-proofing of the basement with the installation of water-permeable openings; floor replacement with a permeable layer of gravel, and elevation of the critical systems above the Design Flood Elevation.
- Thermal and acoustic insulation of all existing surfaces, and thermal insulation in the interior walls; thermal insulation and fire prevention measures for the first floor; replacement of windows and HVAC and DHW system; installation of photovoltaics.
- Elevation of the building through the construction of an add-on (1 or 2 levels), respecting the volume allowed by the regulations (NYC Department Of City Planning, 2014)

- Reinforcement of the existing structure to cope with the extra loads imposed by the add-on.

The flood-proofing and deep energy renovation of an existing building with volumetric addition was documented on a building located in Pioneer Street in Red Hook, presenting similar characteristics.

Figure 2. Red Hook area selected for investigation as part of the High-Risk Flood areas

The simulation phase aimed to establish, through the energy consumption data, the economic feasibility of the various scenarios proposed. The analysis was then carried out in two distinct phases: Energy Simulations and Analysis of costs and payback time. To deal with a large amount of dynamic simulations to be performed (4 scenarios, 3 types, 8760 hours to simulate) a parametric analysis of all the variables was necessary. Energy simulations were performed with the use of the parametric modeling software *Grasshopper* and specifically the energy modeling plug-in *Honeybee* (Grasshopper, *Ladybug Tools*). Honeybee interfaces directly with *EnergyPlus* simulation software of the *Department of Energy*. The cost analysis and the determination of the payback-time, instead, were carried out with the help of a tool developed by *ABRACADABRA* (*Financial Toolkit – preliminary report – M19*," 2017) and modified specifically for the case in question in order to consider the parameters related to flood proofing and flood insurance.

The state of existing buildings has been assessed considering: energy demand, CO_2 emissions, annual insurance premium cost and cost projection at 50 years, operating temperature. Furthermore, a series of important geometrical and constructive aspects along with the building orientation have been analyzed in relation to the actual heating and cooling loads.

Different scenarios have been simulated and compared that are listed below with their findings.

Deep Renovation as initial state, is related to the energy related components of the building, not eliminating its vulnerability to flooding. This simulation is necessary in order to assess the environmental sustainability of this intervention and to highlight its (low) profitability (32 years of pay back time).

1) Flood-Proofing + 1 Rooftop Add-on

Retrofitting for Flood-Proofing means the loss – for residential uses - of the spaces below the Design Flood Elevation. These spaces are then recovered through the add-ons built over the existing building. Even if this is a non-energy related retrofitting operation, it was decided to include a photovoltaic system: after Hurricane Sandy impacted Red Hook, the neighborhood remained without electricity for a month; for this, the installation of a PV system can be considered a Flood-Proofing measure. Furthermore, in the case of Van Brunt Street, since the ground floor is designated for commercial use, the only viable Flood-Proofing strategy is the Dry Flood-Proofing. This results in a reduction in the insurance premium of only 50%. However, it was decided to increase the volume of the building as allowed by the category of zoning (Fig. 3).

2) Deep Energy Renovation + Flood-Proofing + 1 Rooftop Add-on

This scenario simulates the combination of Flood-Proofing and Deep Renovation with a volumetric addition. In the cases of Van Brunt and Pioneer Street (Fig. 3) it was possible to evaluate the sale and rental of the additional volumes. Instead, it was not possible to do the same for Visitation place where, as said before, the volumetric addition remains a compensatory measure in favor of the current tenants who would otherwise see the available usable area reduced. In this scenario Pioneer Street and Visitation Place Buildings are brought up to zero energy (thanks to oversized PV Plant), while Van Brunt stands at around overall 93% energy savings.

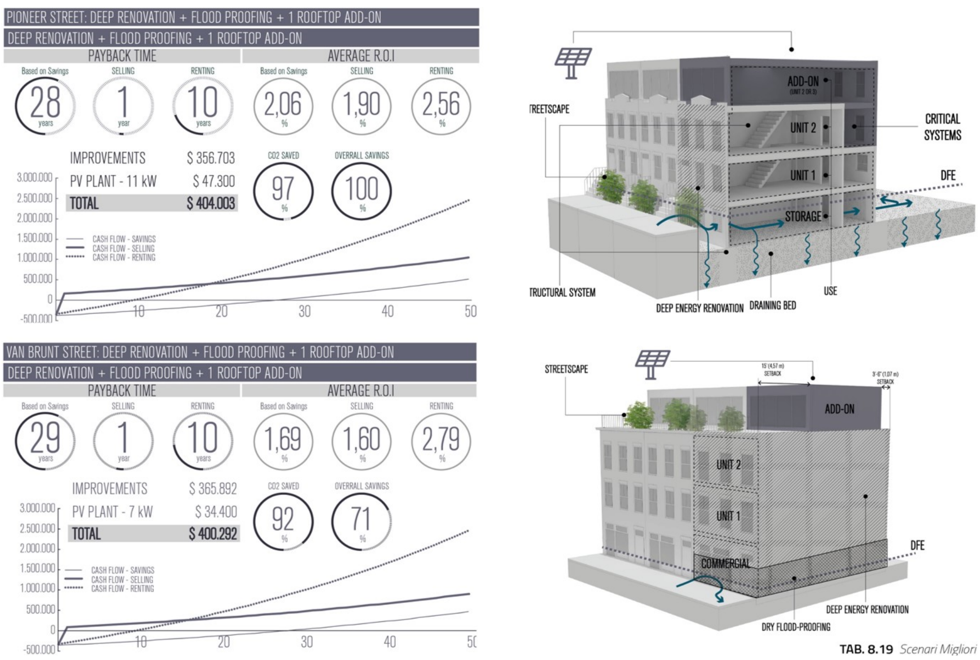


Figure 3. Simulated scenarios for i) Flood-Proofing + 1 Rooftop Add-on, ii) Deep Energy Renovation + Flood-Proofing + 1 Rooftop Add-on

Given the poor economic convenience of Deep Renovation, Flood-Proofing in all the three considered cases, the combination of Flood-Proofing and Deep Renovation always presents a far higher economic attractiveness. In all the cases the required 80% of CO_2 emissions reduction (97%, 92%, 81% for Pioneer street, Van Brunt Street, Visitation Place respectively) is achieved.

As further analysis, the strategy has been tested also in a different case scenario and a different urban reality (Kallithea area, Athens Greece) where seven different scenarios have been foreseen and studied, as shown in Table 1.

Table 1. List of the seven different scenarios proposed for the urban retrofit of the urban plot in Kallithe area (Case B)

Scenario	Description of the intervention
0	Deep Renovation intervention applied to all 19 buildings constituting the parcel (application of external thermal insulation composite system, roof insulation, replacement of window frames and systems)
1	*AdoRES* on-top extension applied only to the South-West portion of the parcel, thus including Block 1, Block 5 and the interposed building
1a	Variation of Scenario 1, which envisages only the construction of Block 1 and AdoRES
1b	Variation of Scenario 1, which envisages only the construction of Block 5 and AdoRES
1c	*AdoRES* on-top extension, considering the requalification of the surrounding buildings with the maintenance of the volumes
1d	Most significant interventions applied to the single Block 1
2	Construction of 5 new Assistant Buildings, realization of one *AdoRES* on-top extension and redevelopment of the other 11 buildings

Figure 4. 3D modeling of the precise batch selected among those of Kallithea: (a) Aerial view with individuation of the categories of building (A-G); (b) Axonometric view of the south-east fronts (© 2019, C. Masinara), on the top.

(a) (b)

Representation of the possible deep renovation interventions: (a) Exploded axonometric representative of the strategy that foresees the realization of the endoskeleton with on-top extension; (b) Top view of the plot after the interventions (© 2019, C. Masinara), at the bottom.

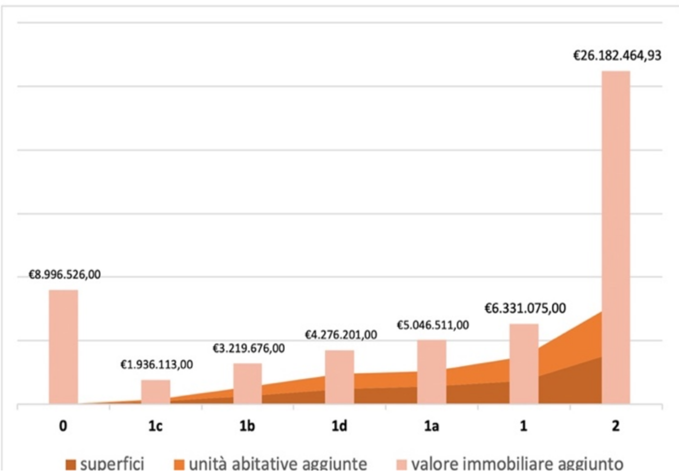
The research has preliminarily defined a list of hypotheses concerning the current situation of the real estate market and construction costs, identifying the prices [€/m^2] with reference to the following interventions:

- deep renovation (for existing buildings);
- demolition (in case of replacement);
- construction (for new buildings);
- real estate value (potential gain from the sale of new units).

For the last item, the average selling prices of buildings in the area were considered, slightly increased to take into account the higher energy performance of new buildings, aiming at the nZEB building standard, identified by EPDB 2010/31/EU, which requires MS to reduce the energy consumption of buildings through new nZEBs.

As far as the cost analysis is concerned, assumptions have been made to assess a price [€/ m^2] for new additions and a consequent sales price. The proposed intervention strategy is based on the principle that the net gains achieved in this way are subsequently used to carry out deep renovations in neighboring buildings.

Considering the Athens' case there is a cost of 300 €/m^2 for the deep renovation, 1,200 €/m^2 for the elevation and a minimum cost of 1,400 €/m^2 for the realization of Assistant Building, variable between the different scenarios, according to the related costs of demolition and installation of photovoltaic systems.



(a)

SCENARI	(pay-back)	+ (house)	+ m^2	+ €
0	40 anni	0	0	8.996.5
1c	2 anno	2	214	1.935.1
1b	1 anno	7	660	3.219.6
1d	1 anno	12	1198	4.276.2
1a	1 anno	12	1412	5.046.5
1	1 anno	19	1858	6.331.0
2	1 anno	39	4073	26.182.4

(b)

Figure 5. Data analysis related to the seven different scenarios of intervention proposed by the project: (a) Comparative graphs of the scenarios in terms of housing surfaces, additional housing units, added building value; (b) Table resuming for each scenarios the pay-back time, the increase of housing units, the increase of housing surface and the increase of building value after the interventions (© 2019, C. Masinara).

The table in Figure 5 represents the summary of the analyses carried out on the 7 scenarios. It is possible to see how the added real estate value augments linearly with the additional surface area, thanks to the new densification interventions. This data confirms the success of the densification strategy within already consolidated contexts. It should be noted that the best solutions result from the ones set out in Scenarios 1 and 2, i.e. those with a higher number of newly built units. This means that by intervening punctually on the urban voids, currently present in this highly urbanized context, it is possible to balance the redevelopment interventions, resulting in very short payback times for initial investments, and thus recreating a visual and composing unity in the area. Moreover, it is interesting to note that the solution is feasible both on an architectural scale (shown specifically with Scenario 1d) and on an urban scale (Scenario 2), considering the whole block as a *unicum*. Finally, the results obtained in Scenario 1 and all its declensions should not be underestimated: in these structural emptying interventions, the costs of controlled demolition and subsequent structural consolidation of the existing façades are considerable, doubling the costs that would have been incurred in case of complete demolition. In conclusion, all the scenarios that envisage this type of intervention present considerable added values, thus resulting in effective interventions, from an aesthetic-architectural, performance and economic point of view.

CONCLUSIONS

After a preliminary phase of study of the urban and architectural context of the intervention, the cataloguing of the structures suitable for the implementation of volumetric additions has been conducted, based on the architectural and structural characteristics, followed by the development of design hypotheses for the individual categories and finally by the design development of the most suitable hypothesis. Definitively, the energy and economic checks carried out using the toolkits developed within ABRACADABRA led to positive results. The precise densification of urbanized areas is therefore confirmed as an optimal solution to the twofold need to redevelop the building heritage and reduce the consumption of urban land.

The results reached by this work demonstrate how the add-ons, combined with energy and other non-energy related aspects may reduce the payback times of the investments, increase the real estate value, while providing an extraordinary opportunity to enhance urban resiliency in highly populated metropolis facing the challenge of evolving climate change.

To achieve these results in practice, public authorities should abandon existing regulations in terms of urban capacity, standard limits, and land-use constraints. Of course, the possibility to make these exceptions should be closely linked to the highest target in terms of energy efficiency (towards nZEB), environmental impact and social acceptance.

Although this may emerge as a theoretical and ideal framework, the case study analysis show that densification and extension are already a reality in the construction market many EU and US cities: the next possible, although challenging, step is to link this reality to the deep energy renovation of existing buildings to achieve an effective synergy between the old and the new, with the concrete possibility of achieving an overall balance in terms of energy, costs and land use.

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