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Deep renovation up to zero energy through Add-ons: the ABRACADABRA Project

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1 Abstract

Though housing is one of the most energy consumer sectors, it is currently extremely underestimated, because of a clear investment gap due to economic, social and legislative barriers. The EU project ABRACADABRA (Assistant Building to Retrofit, Adopt, Cure And Develop the Actual Buildings up to zeRo energy, Activating a market for deep renovation) is based on the idea that the real estate value increase given by the appropriate densification strategy in urban environments could be an opportunity to activate a market for deep energy renovation. To prove the effectiveness of the strategy more than 70 case studies throughout the EU cities have been assessed by means of a cost-effective analysis. Basing on the parametric variation of the different values involved (cost of construction, energy, etc.) the benefit of this strategy has been proved in the majority of the different building types and contexts.

More interestingly, the ABRA strategy has been simulated and tested outside Europe in order to verify its scalability and the possibility of considering other non-energy related benefits in the renovation of the existing building stock. A specific study on the NYC urban context has been conducted to effectively adapt the strategy and combine the global drivers of energy consumption reduction and CO_2 emission reduction with the local need of combating flood emergency and related flood-proofing measures.

The results reached by this work demonstrate how the energy retrofit trough add-ons reduces significantly the payback times of the investments, preserve soil consumption, while providing a extraordinary opportunity to enhance urban resiliency by challenging the local emergencies.

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

2 Introduction

ABRACADABRA (Assistant Buildings' addition to Retrofit, Adopt, Cure And Develop the Actual Buildings up to zeRo energy, Activating a market for deep renovation G.A. No 696126) is an European Union funded project [1] 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.

The ABRACADABRA 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, it is possible to limit land consumption and protect the green spaces around cities. The addition of new surfaces as proposed by ABRA would help avoiding soil sealing and could be a strategy for the urban and architectural renovation. This aspect is extremely important because cities and residential building are both facing two challenges: how to find the land to build affordable housing units and how to accelerate the renovation of existing homes.

ABRACADABRA has indeed formulated 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. More than 70 case studies (see fig. 1) have been used to demonstrate the feasibility of the scenarios in different EU contexts using the ABRA toolkits: all selected cases are analyzed to show to potential investors the variation of the pay back times and the new economic value in the different scenarios. 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.

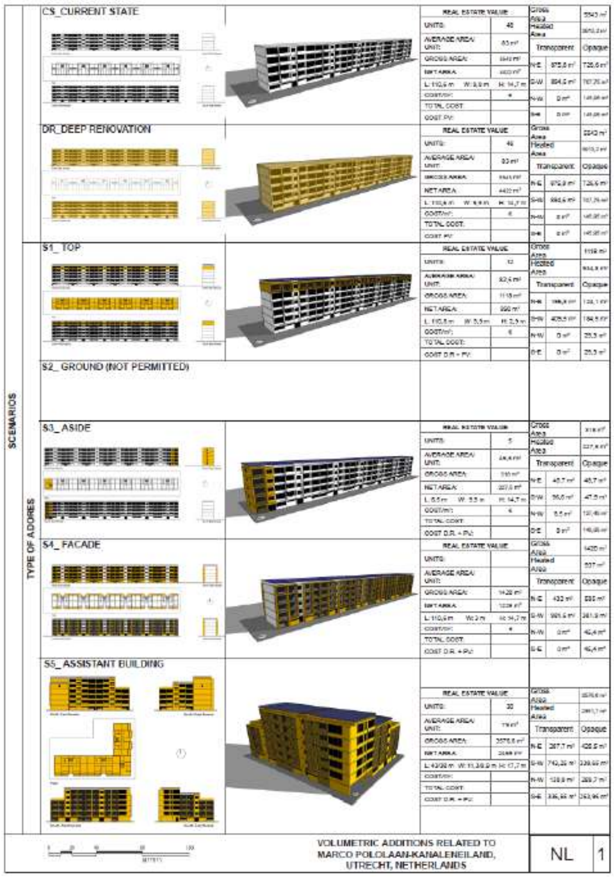


Figure 1. A block building in The Netherlands: one out over 60 case studies used for the cost-benefit analysis in ABRACADABRA

These encouraging results have leaded us to further explore this strategy, through adding new local drivers as other non-energy related benefits in the renovation of the existing building stock. A specific study on a NYC urban area has been conducted to adapt the strategy and combine the global drivers of energy consumption reduction with the local need of combating flood emergency.

3 Scope

Weather emergencies like flood emergency are widely acknowledged: Hurricane Sandy in 2012 highlighted the fragility of coastal areas in New York City. The disaster, estimated to have caused $19 billion in damage [2], pointed out the need to adapt the city and prepare it to face extreme weather events in the future.

The difficulties encountered in the reconstruction further demonstrate the paramount importance of reducing the vulnerability of all the 67,000 buildings at risk of flooding [2]. Despite the seriousness of the situation, however, initiatives to secure buildings (flood-proofing) remain few: only around 1320 buildings have been elevated as of 2018 within the Built It Back Program [3] [4] [5].

The picture becomes more severe considering the increasing likeliness that climatic events of Sandy's magnitude will recur, and property owners are threatened to pay flood insurance premiums that are going to increase, while facing the loss of value of the property itself [6] [7].

The possibilities to reduce this vulnerability and thence reduce premium costs are related to the type and the technical specificity of each building [8].

These possibilities are shown in Fig. 2 and they are listed below:

- Relocating
- Elevating
- Wet Flood-Proofing
- Dry Flood-Proofing

The city of New York has also drawn up a strategic plan to reduce CO_2 emissions by 80% by 2050 (based on 2005 levels) [9].

As is already widely known, especially in the EU context, complying with restrictive rules and caps in building energy consumption is easily achievable in the case of new buildings, but more complicated in the case of existing buildings. Difficulties also increase proportionally to the age of existing buildings. Because of these conditions, and in combination

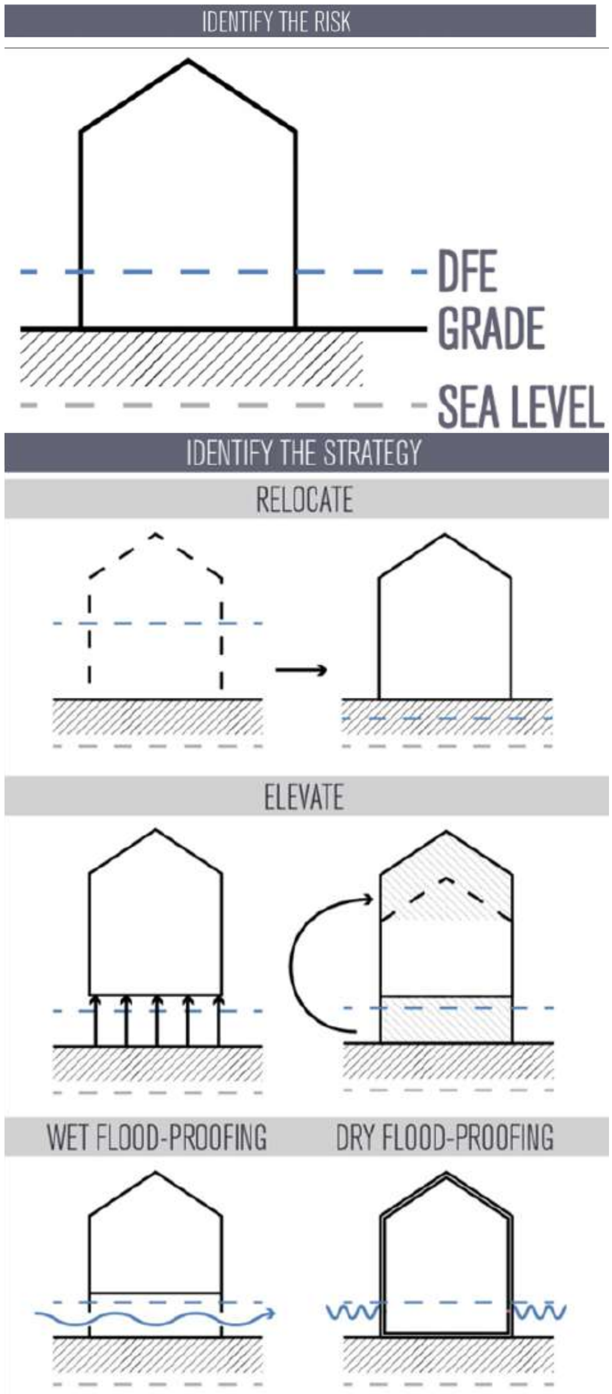


Figure 2. Scheme of the possibilities to reduce the building vulnerability

with a certainly unfavorable federal policy stance [10] the progress of deep energy renovation interventions is far from comforting: about 0,5% [11] (5000/1 million) buildings in NYC are currently being retrofitted within the program NYC Retrofit Accelerator [12].

Figure 3. Red Hook area selected for investigation as part of the High-Risk Flood areas

On the basis of these preliminary notes, a possible research question would be on how to simultaneously stimulate flood-proofing and deep energy renovation, with a goal of reducing global emissions, and enhance urban resiliency.

4 Case Study

To test the validity of this strategy, a simulation has been conducted on a block of buildings in Red Hook (Brooklyn, NY). Red Hook area (see Fig. 3) has been selected as part of the High-Risk Flood areas and one of the neighborhoods hardest hit by Hurricane Sandy and [3, 5] The block chosen for the simulations is located in Red Hook and is between Pioneer Street, Van Brunt Street and Visitation Place. It lies within the A-zone, so it is subject to high-risk flooding and has already been hit by flooding in 2012 during the Hurricane Sandy.

The row houses of Van Brunt Street and Pioneer Street were built at the beginning of the 1900s. In particular, buildings in Pioneer Street have one of the two units (usually rented) located partially below the street level and thus exposed to a great risk of flooding. The buildings on Van Brunt Street have the ground floor occupied by commercial activities and the upper floors by residential units. In both cases, the load-bearing structure consists of two-headed walls and wooden floors. The buildings at Visitation Place were built in the 1970s and are made of rented affordable housing units, but the entire lot is privately owned by a trust. The two units that constitute each building share a blind wall and are developed on three levels. The buildings in the block share an internal driveway for access to garages, which is often flooded by rainwater, as it is located below the street level.

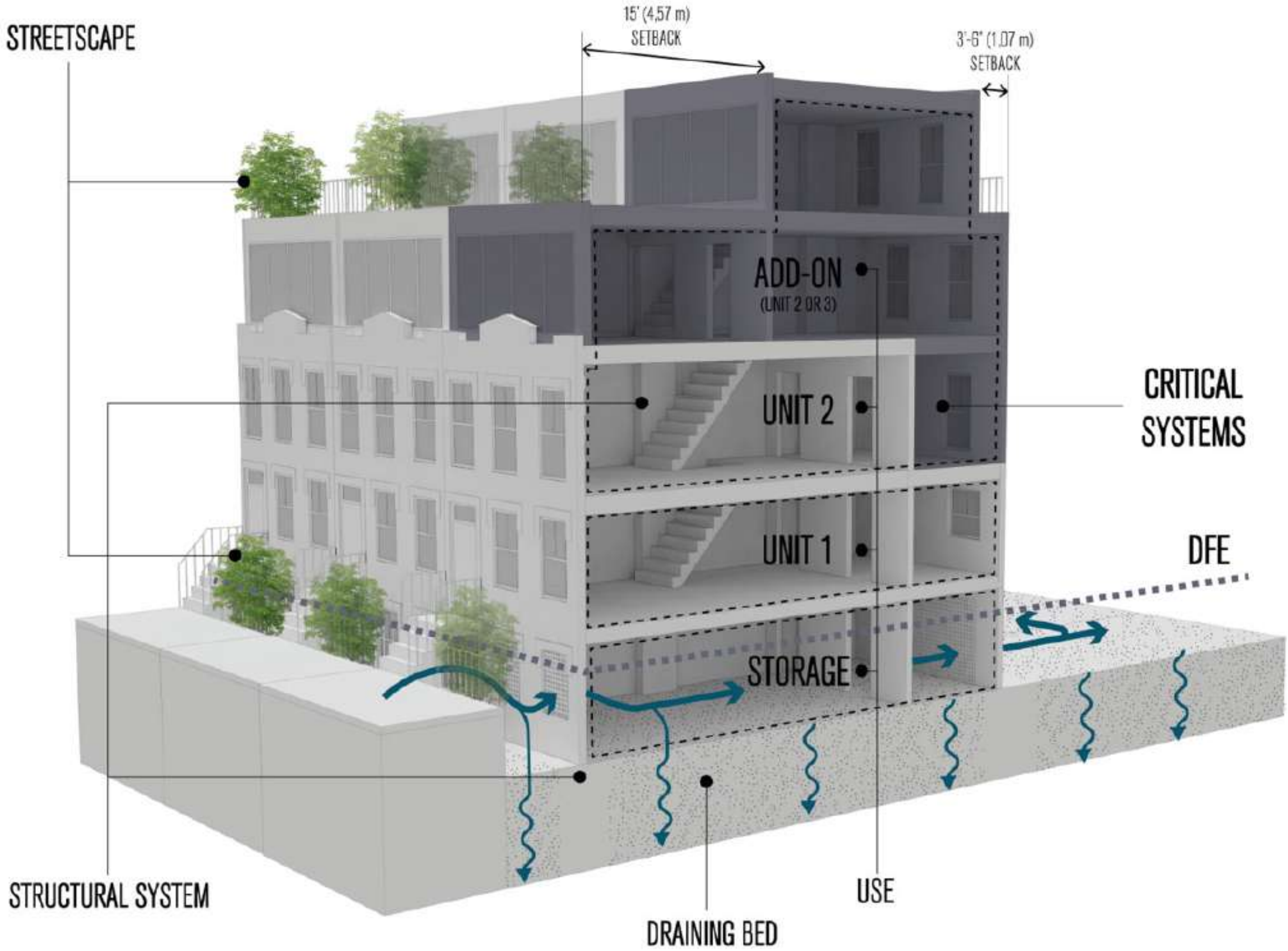


Figure 4. Scheme of the critical parts related to flood proofing and add-ons in a typical building of Red Hook

The 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 [8].
- 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.

4.1 Methodology

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* [13] and specifically the energy modeling plug-in *Honeybee* [14]. Honeybee interfaces directly with *EnergyPlus* [15] 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* [16] and modified specifically for the case in question in order to consider the parameters related to flood proofing and flood insurance.

4.2 Assumptions

Given the high number of parameters (see Fig. 5) and variables involved, the following assumptions have been made:

4.2.1 Performance targets

The performance targets of the individual components have been assessed in accordance with the provisions of the IECC [17]. Thresholds for new buildings were used for both deep renovation and add-ons.

4.2.2 HVAC

For the energy simulation and for the calculation of construction costs, all Energy Star certified systems and appliances were evaluated. The consumption values and average prices of each of the elements are provided directly in the Energy Star guides.

4.2.3 PV plant

The calculation of the photovoltaic area for each building was carried out by calculating the maximum area available and not the real need, so in some cases exceeding it. Once the power of the system was obtained, the average market price of $4,30 [18] per installed Watt was applied.

4.2.4 Cost of Materials

In the absence of official documents on material prices, a specific cost analysis was carried out [19]. Some cost items have been grouped by type of intervention, such as flood proofing measures including demolition, waterproofing, fire-fighting, etc., and the cost of the project has been reduced to a minimum.

4.2.5 CO_2 Footprint

The analysis includes the assessment of the reduction of CO_2 emissions with the aim of reaching (or exceeding) the 80% emission reduction threshold proposed by *One City: Built to Last* plan. Residential Electricity in NYC is produced with various sources, so it was necessary to compose the carbon footprint of electricity production considering each source and in which percentage contribute to the generation of 1 kw [20, 21].

4.2.6 Energy Cost

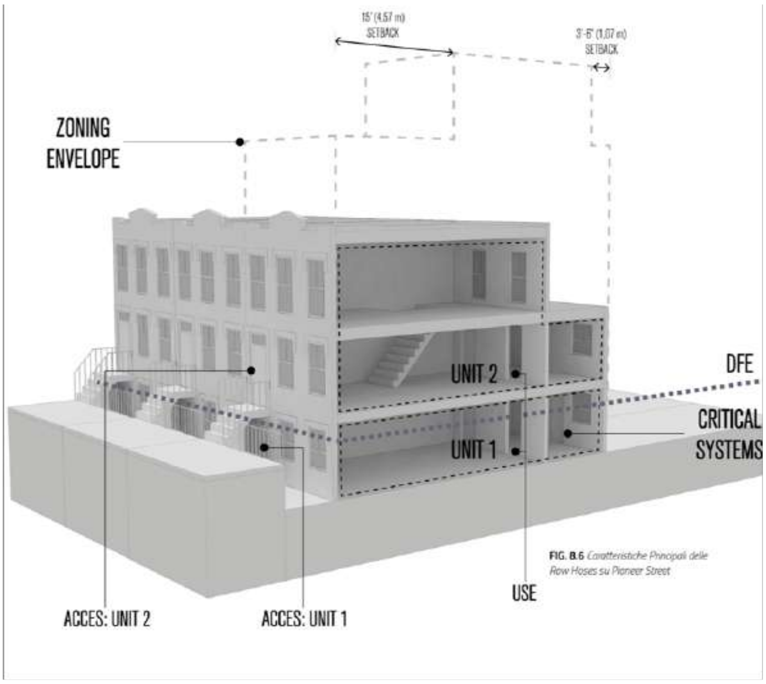
The cost of energy in NYC is susceptible to seasonal variations [22]. The cost of the individual kWh has been established on the basis of the annual average of the last 3 years. Over the last 10 years, the average annual percentage increase has been evaluated and used to assess the evolution of costs in future years. Similarly, the same data could be traced for other energy sources [23].

4.2.7 Insurance Premium Cost

The insurance premium was assessed using the tool [24]. provided by the *Center for New York City Neighborhoods*. The average cost was then applied in the simulation phase. The annual evolution used a 1% annual increase value, which is already unrealistic today. In fact, between the beginning of the study and its drafting, for political reasons, the cost of the insurance premium increased in some cases by 8%. Moreover, this premium is highly susceptible to change due to the occurrence of extreme events: in fact, by increasing the frequency of catastrophic events, the premium increases proportionally [6, 7].

4.2.8 Financial parameters

All the economic simulations were carried out based on a standard 20-year loan, 100% financed by the credit institution and with a fixed rate of 4,50% [25]. Given the complexity of the issue, it was not considered the market assessment of financial products for private consumers, since it is strongly linked to subjective factors such as the credit score.



EUI BREAKDOWN IN kWh/sqm per year	
Cooling	55
Heating	214
Domestic Hot Water	35
Appliances	22
Lightning	9
TOTAL	335
ENERGY COST year 2018	
TOTAL	$ 5402,87
FLOOD INSURANCE year 2018	
TOTAL	$ 6000,00
COST year 2018	
TOTAL	$ 11.402,87

UNITS	FLOOR AREA	CURRENT VALUE	EUI	CO_2 EMISSIONS
1 OR 2	167	1,38	335	12,87
Residential	sqm	Million $	kWh/sqm year	TON year

Figure 5. Parameters and figures for the energy and economic assessment

4.3 Existing Conditions

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.

4.4 Simulated Scenarios

4.4.1 Deep Energy Renovation

Deep Renovation 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 (see Fig. 6).

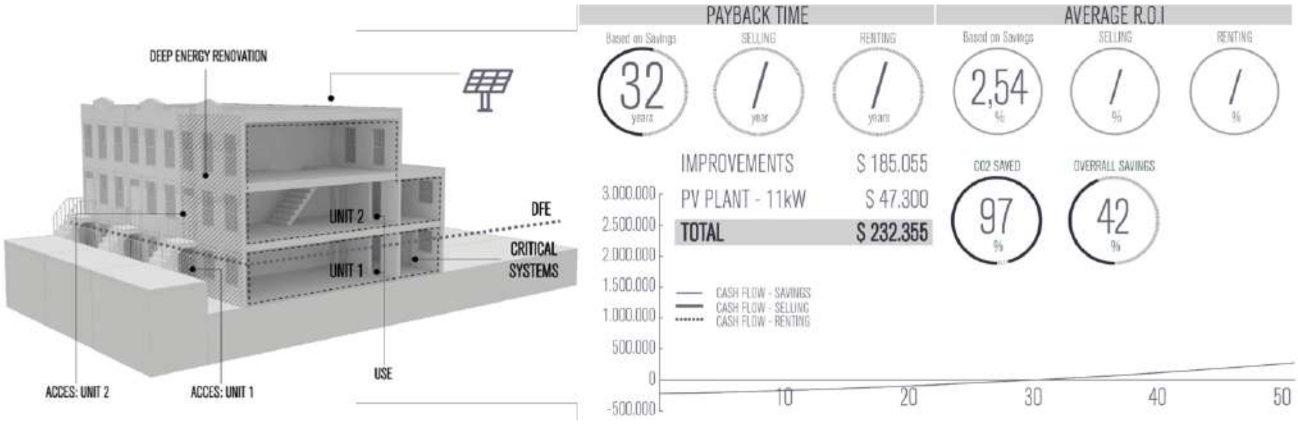


Figure 6. Simulated scenario for the deep renovation

4.4.2 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 (see Fig. 7).

4.4.3 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 (see Fig. 8) 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.

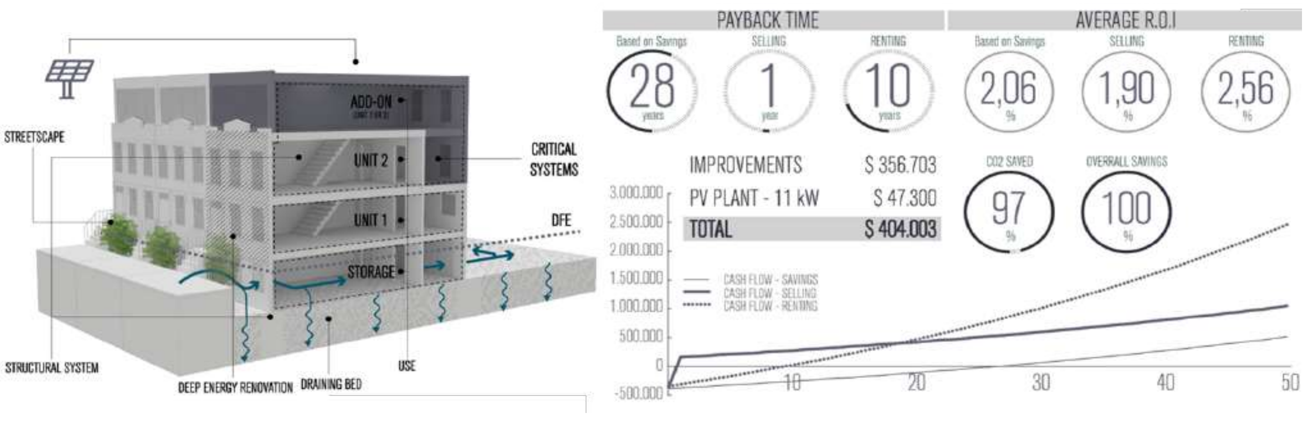


Figure 7. Simulated scenario for Flood-Proofing + 1 Rooftop Add-on

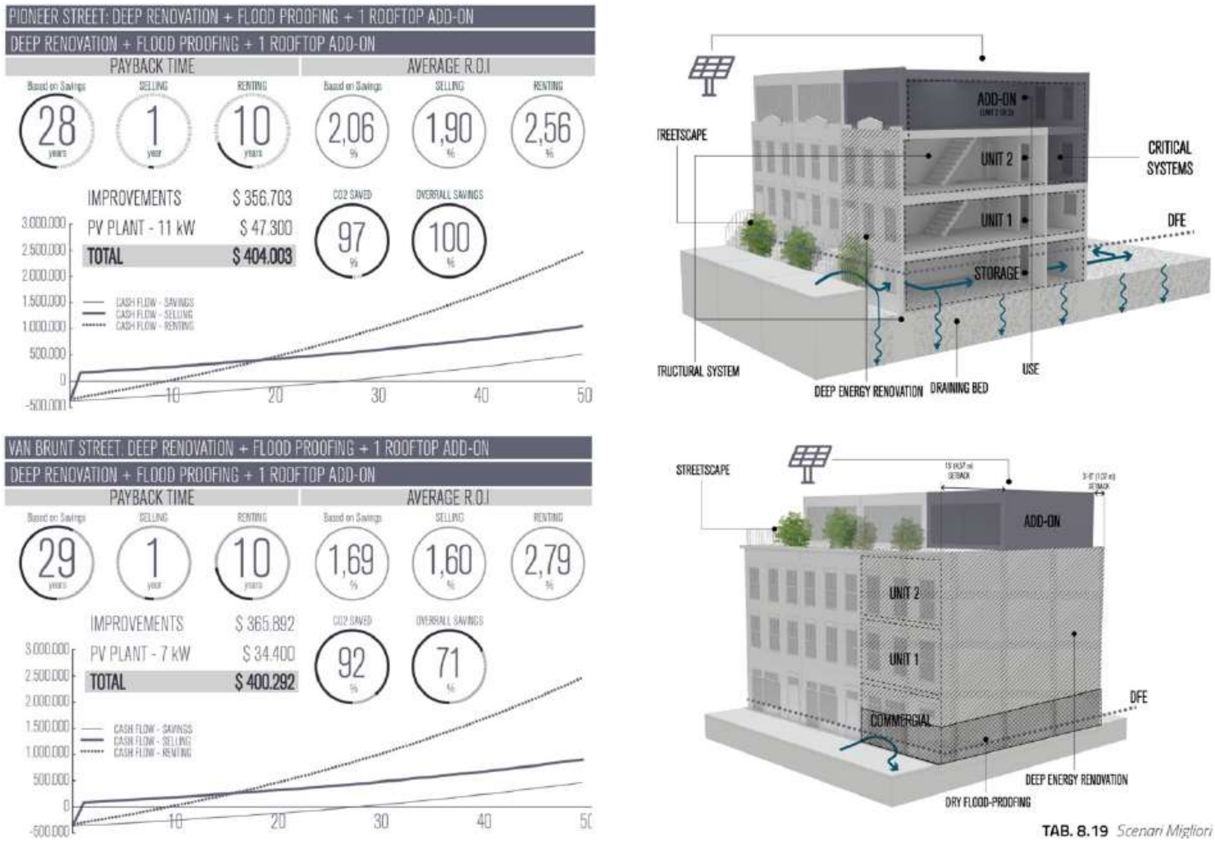


Figure 8. Deep Energy Renovation + Flood-Proofing + 1 Rooftop Add-on

4.4.4 Deep Energy Renovation + Flood-Proofing + 2 Rooftop Add-ons

This scenario simulates the combination of the two interventions of Flood-Proofing and Deep energy Renovation with two volumetric additions.

The Zoning restrictions do not allow the construction of two additional levels on Van Brunt Street, which is not represented here.

On Pioneer Street and Visitation Place instead, two add-ons are viable. In both cases the nZEB goal is achieved (see Figures 9 and 10).

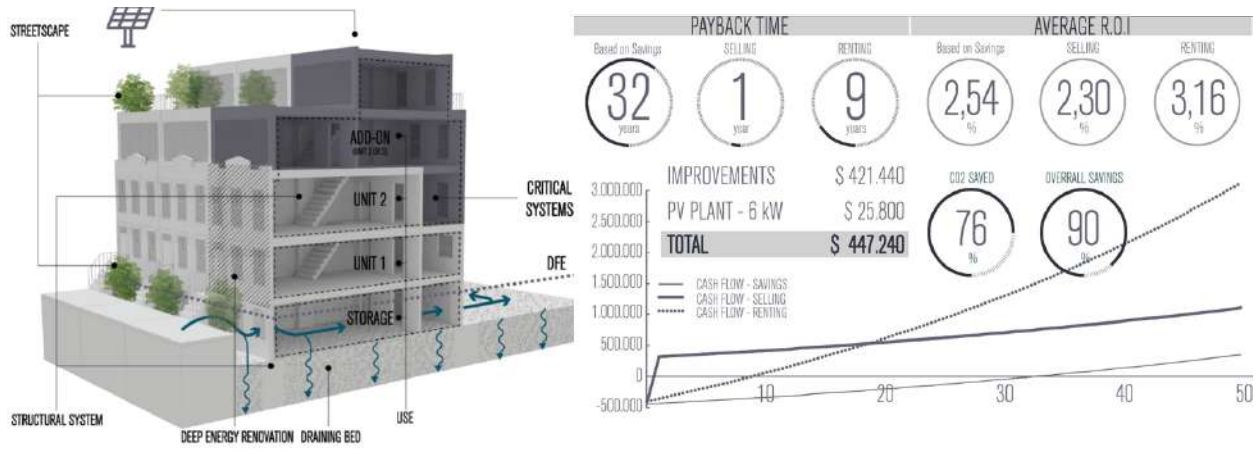


Figure 9. Deep Energy Renovation + Flood-Proofing + 2 Rooftop Add-ons in Pioneer Street

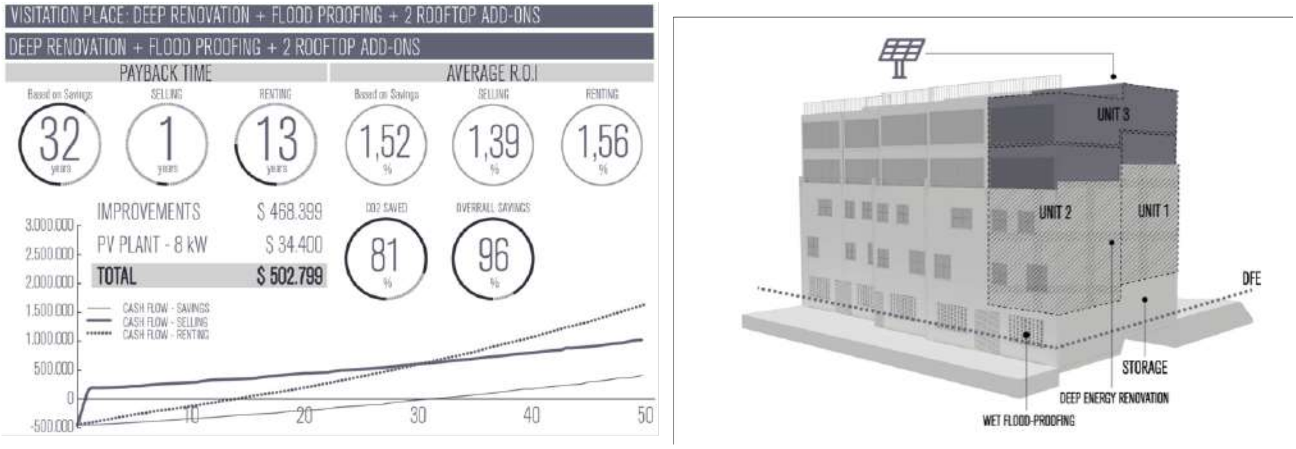


Figure 10. Deep Energy Renovation + Flood-Proofing + 2 Rooftop Add-ons in Visitation Place

4.5 Results

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 CO2 emissions reduction (97%, 92%, 81% for Pioneer street, Van Brunt Street, Visitation Place respectively) is achieved .

Among the results obtained the best scenarios were then selected based on the optimal combination in terms of emission reduction (more than 80% achieved), elimination – or reduction - of the vulnerability to floods, greater energy savings costs reduction of the flood insurance and, last but not least, significantly shorter payback time.

Selling the add-ons is always the best option in terms of return on investment; however, given the specific market price in renting, after 20 years the rent of the add-ons seems more profitable.

5 Conclusions

The results obtained show that the combination of Flood-Proofing and Deep Energy Renovation with add-ons, is not only economically viable but fully satisfies the target of CO_2 emissions reduction and, at the same time, offers a great opportunity to increase resilience in an urban context exposed at an extreme risk such as Red Hook.

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.

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