Green Architecture and Urban Planning

CHANGING CITIES

Deep renovation in changing cities: Densification and real-estate value for cost-effective energy targets in the ABRACADABRA strategy

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Abstract

Europe's energy efficiency challenge in buildings mainly concerns the energy efficient refurbishment and investments in its existing buildings. The European project ABRACADABRA (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 developing innovative actions for deep renovation of the existing buildings and implement a punctual densification policy that aims at fostering the investments in deep renovation of the existing built environment throughout Europe (EU). This paper presents the implementation of the ABRA strategy in selected case studies throughout EU and an in-depth investigation of an urban compound in the metropolitan Athens area.

Keywords: densification; compact city; add-ons; real estate value; nearly zero energy

1. INTRODUCTION

Cities are the "guilty victims" of energy demand pressures and climate change [1]. Urban areas are responsible for the 80% of the overall energy consumptions in Europe [2], thus a greatest challenge is represented by the energy consumptions' reduction of existing buildings. Furthermore, fuel poverty and global overheating is severely threatening the built environment and its inhabitants in Mediterranean area. Increasing urbanization has noticeable consequences on the thermal degradation of urban climate and the energy efficiency of buildings. With regards to this, the new concept of nearly Zero Energy Building (nZEB), which represents the main future target for the design of new buildings, is now gaining increasing attention in relation to the renovation of existing buildings. Thus, the effective reduction of energy consumption towards zero energy buildings and urban settings is and remains an inevitable objective in urban contexts.

This paper attempts at providing a contribution and response to the following research question: is it possible to envisage a sustainable transformation of the existing built environment? In particular, is this sustainability achievable in economic and environmental terms? To do so, the paper presents and discusses some progresses in low and zero energy buildings, illustrating a set of demonstration projects and considering the technical, economic and environmental feasibility of nZEBs. These demo-projects are located in different cases throughout Europe; the paper illustrates, in particular, a selected compound of the Athens Metropolitan Area (AMA).

Further reflection on the estimated costs of proposed energy retrofitting options, has indicated the possibility of higher transformation to counterbalance the consistent up-front costs of energy retrofitting measures.

2. DEEP RENOVATION SCENARIOS IN EXISTING BUILT ENVIRONMENT THROUGH ADD-ONS

The high investment's costs in energy retrofitting have driven some experiences at EU level as well as pilot cases to focus on the strategy of rooftop extensions as additional volumes to counterbalance these costs. Performed cost-benefit analysis in a large set of reference buildings in different contexts 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. Deep renovations of this kind have higher costs than "lighter" standard solutions (new plants, insulations, new windows) but the reduced payback has a very positive effect on the technical and economic feasibility. In addition, these schemes for add-ons and deep renovation could also be implemented on a step-by-step scale if pre-financing opportunities are limited or not available to cover the up-front costs. Hence, new assistant buildings could be considered as the triggering start of a renovation roadmap that would suggest logical and subsequent (for technical and/or economical reasons) renovation steps to be undertaken.

To explain such a strategy, 4 hypotheses have been envisaged (iv) for the comprehensive renovation of a building of about 3.000 m2 with 30 residential units of 100 m2 each (600 net m2 per floor) and a time lapse of 40 years. The different scenarios consist of: i) The "as built" case of a building block consuming 180 kWh/ m2*year; ii) a step by step renovation where the plant system renewal is undertaken during the first year with a consequent 30% of energy consumption reduction (ECR) and after the first 10 years the replacement of windows' components (+15% ECR) with high energy performing windows; after 20 years all the surfaces of the building envelope undergo renovation (+25% ECR); iii) the construction of a new building (assistant building) aimed at reducing only the 20% of the actual building; (iv) finally, the combination of a step by step renovation with the construction of an assistant building of about 1000 m2 built with passive standards (15kWh/m2*year) and producing energy from RES for its own requirements as well as for the requirements of the "adopted building" (Fig. 1). In this hypothesis the assistant and assisted building are equipped with a PV system to set to nearly Zero the energy consumption of the two buildings (A total 21,231 kWp PV plant for the assisted and assisting building has been considered to cover 187.600 kWe for the total net residential surface of 4000 sqm.).

The previous figure shows how the assistant building acts as a trigger in a stepped renovation process. It can be designed to act as the catalyst or 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.

The simulated scenario previously presented considers the hypothesis of the inhabitants/property owners as direct investors: it is the basis to calculate the revenues of a potential ESCO or a Construction Company (or a joining venture among them), as simplified in the scheme reported in the following Figure 2.

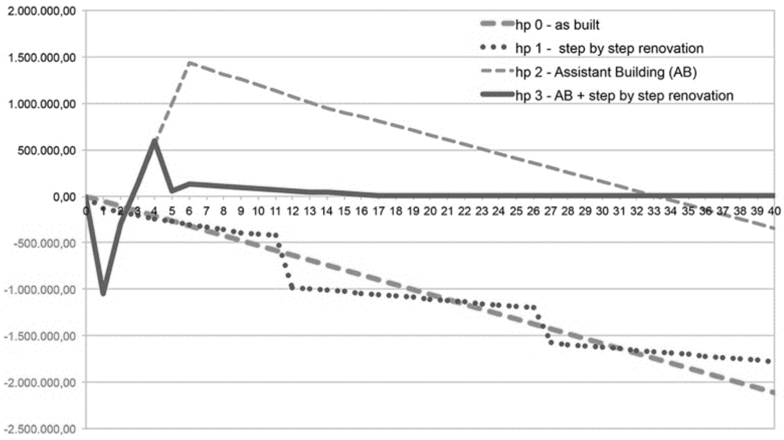

Figure 1. Cost-benefit analysis performed in the building model. Results show how the construction of an Assistant building can be integrated in the process of a step-by-step renovation. On the right, calculated cash flows for the different hypotheses. Of course it is important to specify that in the hypothesized scenario need to be considered a new (lighter) investment after a time lapse of 35-40 years.

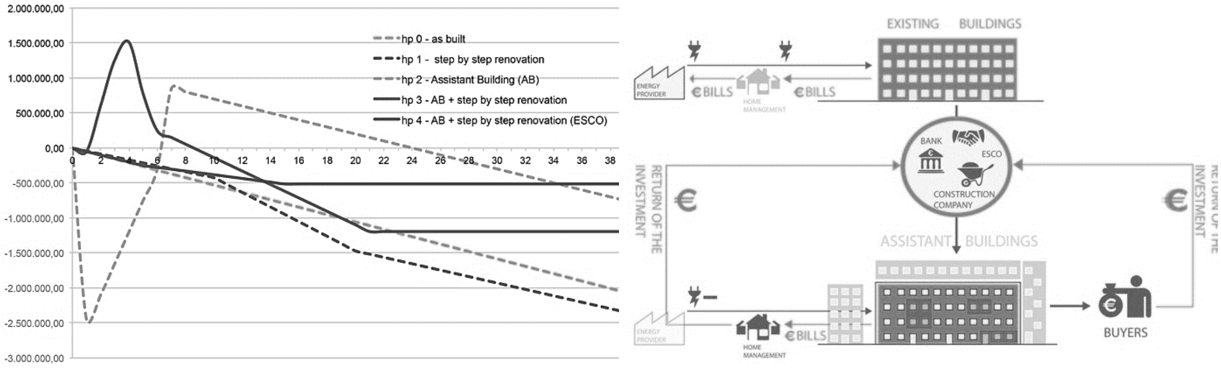

Figure 2. On the right, scheme of potential actions to be undertaken by an ESCO or a construction company CoCo in the construction of AdoREs and retrofitting of an existing building. In this case ESCO/CoCo have return of investments from the combination of both AdoREs's revenues and energy bills from the existing buildings' inhabitants or house manager. The combination may result in a **win-win solution**: in fact, on the one side the dwellers or owners may benefit from a reduced fee or a reduced number of years to reimburse the ESCO/CoCo and on the other side ESCO/CoCo will receive revenues which can be immediately available from the first 5 years. In this case financial interests for Banks and Esco have been considered in the diagram on the left.

Results in Figures 1 and 2-show evidence that the provision of a new building with few or no links with the assisted building does not produce long-term investments. On the contrary, in the hypothesis of establishing a binding contract between the construction of an assisted building and the renovation up to nZEB of the assisted or adopted building, a more stable investment climate for market and social actors can be achieved. In fact, on the one side the occupants or owners may have a reduced fee or a reduced number of years to reimburse the investor (Esco-Construction Company) and on the other hand the same investor(s) will receive revenues, which can be immediately available within 5 years. This can also result in the co-related benefits of reducing risks, of releasing funds for further investments, thus stimulating other deep renovations in a faster, but well-planned, long-term market strategy. In addition to the evidence of the resulting increase of scale and impact of the deep renovation processes, it is important to highlight how the scheme minimizes the disturbance for inhabitants: they are generally able to remain in their apartments during the renovation works and, where possible, they will keep paying the bills through the usual system, being the provider part of the process. The additional spaces can then be distributed or combined in the three following options, according to the different contexts: 1. Extra living space for the existing units as bonus to the inhabitants that contribute to the investments; 2. Additional units and surface adjoining the blind facades of the buildings, and/or the roof top addition; 3. The Assistant Building to financially support the renovation investment and reduce the pay-back time. In this case the Assistant Building may consist of a bonus, a complementary economic instrument for the investors 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 from the inhabitants in paying the bills.

Abracadabra strategy overall aims to build confidence and demonstrate the attractiveness of a new renovation strategy based on volumetric additions- Add-ons and Renewables. This is a set of assistant units integrated with renewable sources. From “DEEP RENOVATION” up to 4 different possible scenarios such as additional units attached to aside blind facades, ground volumetric saturation, roof top extensions, extra living space on main facade in existing units, and “ASSISTANT BUILDING” where a separate building (on the same premises) is added. Add-ons and renewables (“AdoRES”) can be built in numerous ways, regarding the different urban contexts and building types. The different schematic scenarios can be visualized in Figure 4.

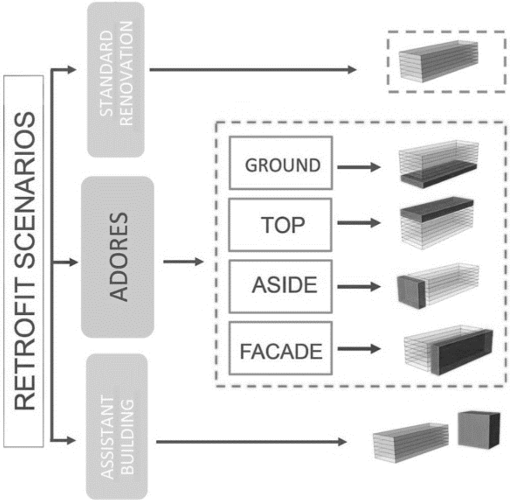

Figure 4. Categorization of possible additions in existing buildings

The first implementation in the Abracadabra project has produced a feasibility study scheme, suitable to evaluate different options for AdoRe implementation in different building typology. Data on the case studies (pilots) from the different countries have been collected and a preliminary analysis of the “as built scenario” has been developed for assessing the energy performance at the initial state. After this preliminary analysis, a first set of architectural scenarios through Add-ons to be integrated with Photovoltaic panels (AdoRES) has been envisaged. This preliminary study has included the comparison of all possible different options for each case study (Figure 5), based on a first investigation and survey related to energy and construction costs. In this context the following schemes represent the first step for a future procedure that aims at estimating the right entity of admitted add-ons. The cross-geographical approach and the distribution of the different case studies in the wider context of the EU is essential to ensure that the same methodology is applied in the different climatic conditions and for different building types. This procedure is necessary to achieve a competitive economic business result for developers and owners, while avoiding over-estimation of proposed additions and proposing environmental, social and sustainable compensative measures for Public Bodies.

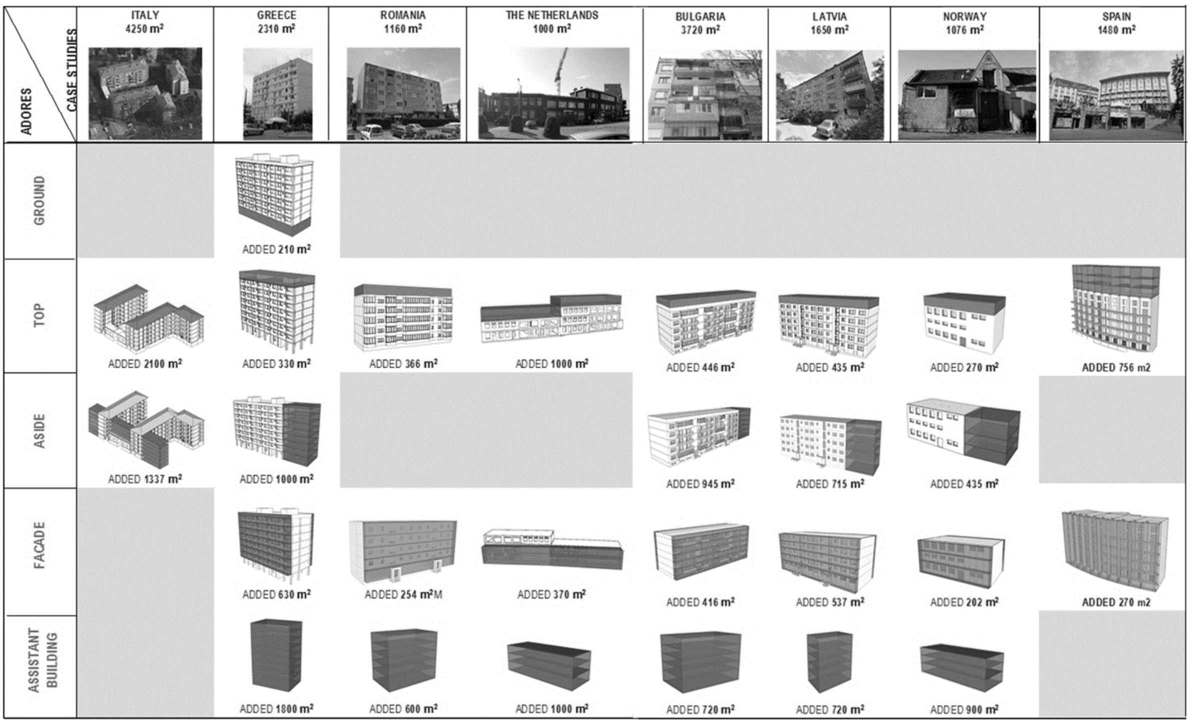

Figure 5. Possible scenarios for AdoRES in each of the selected case studies

3. THE CASE STUDY OF PERISTERI “WORKERS’ HOUSES” URBAN COMPOUND

The research presented to this paper has been conducted on a case study specifically selected for its representativeness, both in terms of geographical location (the western part of Athens Metropolitan Area –AMA- characterized by higher level of Heat Island phenomena [3] and for its construction type. In fact, the building types - a series of block buildings with a structure made of reinforced concrete and infill walls- is massively present throughout AMA suburbs and typically connected with similar building blocks all over Europe. In this typical urban setting, performed simulations have been conducted and resulted in extremely low energy performance at the initial state of the existing compound’s buildings. Alternative retrofitting and design scenarios have consequently been studied and simulated, proving the technical feasibility of reaching the nearly ZEBs. Thus, the research study has hypothesized the introduction of both dense and mass consistent coating materials to achieve the improved thermal performance in the summer the winter seasons. Peristeri due to its geographical position is the area with the highest summer temperatures. The workers' houses urban compound (Figure 6) is characterized by the presence of massive volumes with different building types and building geometry. In particular, the compound consists of 12 buildings:

1. Three "tower buildings" (T11);
2. Three double building blocks north-south oriented (B6);
3. Four building blocks east-west oriented (T7);
4. Two building block north-south oriented (A7).

Figure 6. Peristeri Urban compound selected as reference case study

The urban compound's extension is 37.820 m2, of which 25.713 (68%) is occupied by buildings and impermeable surfaces (parking areas and streets); the remaining (32%) is a green open area. The build area accounts for a total of 7.504 m2 (29%) of the overall impermeable surfaces.

3.1. Energy performance evaluation in the as built environment

The structural system of the buildings is very simple, made up by a regular grid of beams and pillars, with presumably prefabricated slabs as horizontal elements. The main thermal parameters and transmittance values have been hypothesized according to the technical details for the ground, intermediate and roof slabs as well as for the external building envelope partitions. Simulations have been performed by using DesignBuilder, a fully equipped interface using EnergyPlus platform to calculate and estimate the energy performance of buildings. EnergyPlus is the U.S. Departments of Energy's 3rd generation dynamic building energy simulation engine for modelling building, heating, cooling, lighting, ventilating and other energy flows. It has been validated under the comparative Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs BESTEST/ASHARE STD 140 [4]. The thermal analysis of the as-it-is condition has been performed for each building type in the reference urban context of Peristeri.

A selection of representative units (apartments) has been made according to both the position of the unit within the building block and the solar orientation, assuming that neighbouring units will perform similarly from an energetic point of view. Energy simulations have been run for each building types both in cold winter and hot summer seasons. As expected, the most consuming units (both in summer and winter season) are the apartments located at the last floor. As also expected, the less consuming units (both in summer and winter season) are the apartments located at the intermediate floors. Substantial difference in the energy demands of the units may also be observed comparing the residential units in a same floor location, but with different solar orientations.

3.2 Energy retrofitting scenarios and cost-benefit analysis of existing buildings in Peristeri urban compound

To evaluate the technical and cost-effective feasibility of the possible energy retrofitting options in the Peristeri case study, a series of transformation - gradually increasing, from the sectorial to the far-reaching - have been considered on the different buildings' types. These transformations produce the following possible scenarios: Scenario_1: Wall insulation (walls and lower floor on "pilotis"); Scenario_2: Windows' replacement; Scenario_3: 1+2 Combined scenario; Scenario_4: Roof Insulation; Scenario_5: Roof Insulation and green roof; Scenario_6: 3+5 Combined complete scenario. The Results of the performed simulations according the above-described scenarios are synthetized in the graphs reported in the Figure 7.

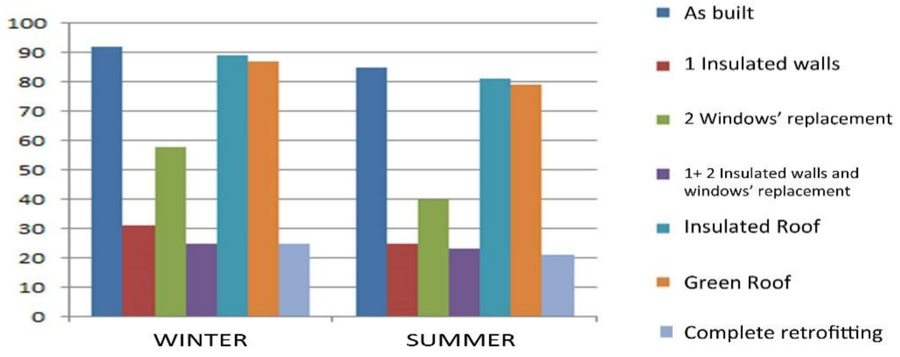

Figure 7. Possible energy retrofitting options in the single block building and correspondent savings in terms of energy performance indexes (kWh/m^2*y)

To identify the economical feasibility of the energy retrofit scenarios, a cost-benefit analysis was conducted by means of a market survey, determining, for each different design option, the evaluation in terms of energy performance improvement and the related cost estimations. Thus, a cost-effective analysis has been developed for each building type and for each different scenario. The simple pay back time of the investments corresponding to the intervention scenarios have been calculated and the synthetic results of these calculations are illustrated in Figure 8.

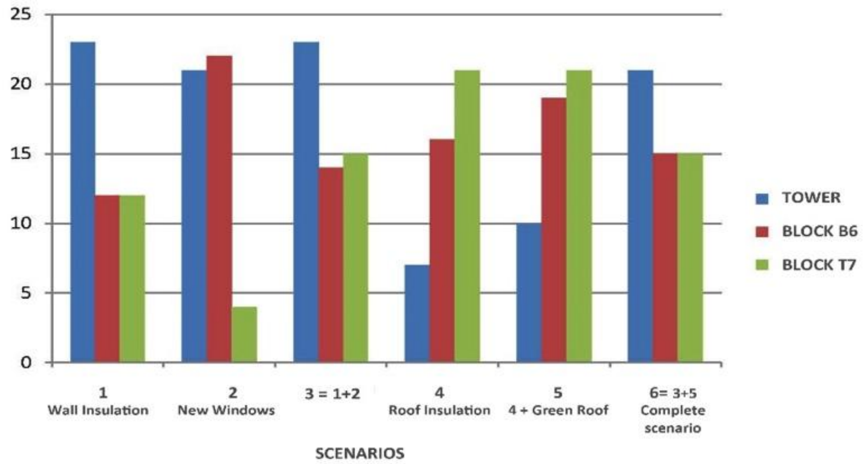

Figure 8. Pay back time of the investments range widely: a variation between 23 and 7 years can be observed as function of the different hypothesised scenarios for the three illustrated different building types (B6 = double building block; T7= single building block).

Performed evaluations on cost-benefit assessments of all the considered scenarios interventions generally show excessive payback times (up to 10-20 years and more). Furthermore, these analyses do not yet include the installation costs of RES plant and plant renovations that are crucial to set to zero the energy balance of the selected buildings. Thus, the energy retrofitting in the existing buildings of Peristeri urban compound is proved a technically feasible goal. Although, it is necessary to face the problem of very high costs due to the need of the operation for both active and passive interventions, which are amortized over a relatively long period, generally comparable with the life of the systems of energy production from RES.

A detailed diagnosis of the individual residential units have shown that it is possible to reduce the average Energy Performance (EP) down to 20 kWh/m2*y, for winter and summer respectively, by insulating opaque surfaces –roof and walls- and replacing existing windows (complete retrofitting scenario). Passive retrofitting interventions and energy production from renewable sources are both necessary to achieve nZEBs in the retrofitting of highly energy consuming buildings: this is exceptionally challenging considering the specific context of the considered urban compound and the general crisis in the Mediterranean area. The reflection on the estimated costs of proposed energy retrofitting options clearly underlines, once again, the need for additional strategies and measures at social, public, legislative and market level, to counterbalance the excessive payback times of energy retrofitting measures. In particular, it is necessary to activate new forms of incentives in order to attract potential investors as well as dynamically involve the social participation to motivate urban dwellers in the energy retrofitting of their urban environments.

3.3 Low-versus-High transformation retrofitting options towards nearly Zero Energy in existing buildings

This paper has envisioned the possibility of a higher transformation of the existing buildings through the creation of additional units and new facades (Figure 9).

Figure 9. Structure frame for the T7 block type. Technical study of the structural feasibility to combine additions on the top and aside the buildings (and thus new residential units) with façade additions.

The hypothesis of buildings' transformation has been based on the assumption of creating both additional spaces for users and inhabitants in the current residential units, and new additional units for potential investors. Furthermore, the possibility to combine add-ons on the top and aside the buildings (and thus new residential units) with façade solutions encountering different users' needs have been explored (Figure 10) for the block building types [5]. Further economic analysis has been developed to test the feasibility of the previously envisaged scenarios.

Results reported in the following Table 1 show that in each building type the incremental units and add-ons represent an effective strategy to decrease the long payback time of the energy retrofitting.

Table 1. Cost-benefit assessment of the "deep retrofitting", including the creation of new units in the building type T7

Retrofitting options T7 (28 units)	**Costs/Gains related to the option**	**Saving**	**Pay Back Time**
	€	€/year	year
A – Complete retrofitting	-280.717	18.704	15,0
B – Metal structural frame	-174.319		
C – Solar and PV plants	-236.800	30.800	7,7
D – Construction of new residential units	-1.582.000		
Total costs/investments	-2.273.836		
G - Gain from new units	1.924.000		
Total	**-349.836**	**49.504**	**7,1**

As showed in Table 1, the potential gains related to the construction of new residential units greatly decrease the pay back time of all the initial costs of investment, including the RES required to set to zero the energy balance of the buildings. Furthermore, if we consider the hypothetic investment of developers in add-ons, the gains obtained by sales of the new flats would be close to counterbalance both the standard energy retrofit and the cost of RES (PV and solar panels) to set to zero the energy demand of the whole building. The energy analysis on the different building types in Peristeri, have demonstrated the energy saving potential of different "standard" retrofitting operations. Calculations showed that it is technically possible to reach an average Energy Performance (EP) around 35-60 to kWh/m2*y, by the insulation of opaque surfaces and the replacement of existing windows. However, the cost-benefit assessments of these interventions have always showed excessive payback times (up to 10-24 years without incentives).

Thus, the research design simulation has considered the costs of other energy retrofitting operations envisaging the building "densification" by the use of new residential units, new building addition like sunspaces, buffer zones and extra-rooms (add-ons) in the existing units and the integration with RES. These more radical transformation hypotheses drastically reduce the energy performance indexes of the buildings up to the target of a Passive House, which can easily achieve the target of nZEB by a reduced use of RES. Furthermore, the different energy Performance indexes (kWh/m2*y) of the "deep renovation" options have been compared to the relative options' costs. As expected, the higher is the building's transformation, the higher are the costs. Thus, a feasibility study of these volumetric additions has been developed. Results have showed that in case of a hypothetic investment by developers or by the same inhabitants in add-ons, the gains obtained by sales of the new flats would be close to counterbalance both the standard energy retrofit and the cost of RES (PV and solar panels) to set to zero the energy demand of the whole building. It can be concluded that on the side of economical feasibility, the incremental transformation may produce an interesting opportunity to counterbalance the high investment costs of energy transformation.

The connecting theme of the proposed research path is that the crises of energy supply and global warming need to be tackled with an interdisciplinary, both socio-economic and engineering approach. In particular, the design study and the performed technical-economical evaluation demonstrate that energy efficiency in residential urban complex can be considered as an extraordinary opportunity to restore environmental, social and urban quality.

3.4 From the buildings to the open areas

These hypothetical interventions do not negatively affect the availability of open green areas. To properly address the objective of zero energy in existing urban environment, we also need to consider the buildings and the related open areas. A new spatial organization for the outdoor spaces in the Peristeri urban compound has been outlined. A feasibility study was developed to maintain and increase the green and permeable surfaces as much as possible. Access to the open spaces was re-organized to permit people enter the area from the renewed retail and commercial areas into "semi-private" green courtyards and as a result to give a warm and welcoming feeling that would enrich the quality of the communal spaces. In Figures 10 and 11 it is illustrated a proposed master plan taking into account the incremental volumes as designed in the major transformation envisaged so far, including green surfaces and open spaces.

The final configuration combines the need for a more inclusive environment for urban dwellers and the cooling potential of increased green and permeable surface. Thus, notwithstanding a significant increase in terms of urban density, there is still a wide potential for recovering green space and natural open areas in this urban context.

Figure 10 and Figure 11. The area of Peristeri, the existing master plan and the proposed alternative scenarios. The existing green and permeable surfaces are calculated equal to 12.100 sqm, while after the requalification of the urban compound including add-ons the same permeable surfaces can reach 21.780 square meters

4. RESULTS AND DISCUSSION

In the assumption of world population and urban concentration increase calibrated, distributed, and locally-based interventions based on densification and add-ons toward nearly Zero Energy Urban settings present a lot of potential for a two-fold benefit.

In fact, urban densification schemes may signify a process limiting the negative effects of urban sprawl at the territorial scale while achieving a full-scale energy savings strategy.

As shown in the Peristeri case, densification in urban contexts, when combined with a re-organization of open spaces, may even result in the increase of permeable and green surfaces which in turn represent a key role urban climate mitigation [6], the concept of add-ons or new assistant buildings may even open the way for "adopting" existing buildings in areas where no free space is available, for example, in the historical centers. Thus, we might even envisage a scale-up in this process and hypothesize the exchange of "urban quotes" among different areas of the city, where the centers may be "adopted" by new, renovated, nearly zero energy – or even energy plus – urban peripheries [7].

The envisaged actions toward achieving nearly zero urban settings focused on the following main benefit: the generation of a substantial increase of the existing value of the current buildings through significant energy and architectural transformation, in order to go beyond the minimum energy performance and aim at achieving ZEUS. In the search for transitional pathways toward a low-carbon future, in place of large or incremental development plans, we may envision a series of limited, but challenging, nearly zero energy urban settings, which can be conceived as the punctual nodes of a long term re-planning, as they have the potential to generate a new identity for the city as a whole.

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