LCC Analysis to evaluate the economic sustainability of technological scenarios on the district scale

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*key words:*seconomic sustainability, life cycle cost analysis on the district scale, global cost, energy retrofit, technological scenarios, urban regeneration

Abstract

The analysis of the alternative project technologies shapes up as a crucial passage to verify the economic-environmental sustainability and thereby steer the choices of Public Administrations and private investors on investing in the retrofit of assets towards Energy-Efficient Buildings. When it comes, however, to new construction or energy retrofit interventions on existing buildings or clusters of buildings, you cannot overlook to place them territorially within a broader infrastructural vision.

In the essay, we suggest to apply the Life Cycle Cost Analysis (LCCA) approach to assess the economic sustainability of optional technological scenarios. Assuming the methodological principles of the LCCA approach, amply explored on the building scale, we try to reason on the district scale, tackling the complexity that this broader scale perspective entails. At the same time, we suggest application of the LCCA approach to a case already targeted by a previous retrofit intervention: a "post retrofit intervention" viewed within a differently mature technological and market context.

We propose the simulation on a real case clarified by the "Concerto AL Piano" European project, developed as part of the "Concerto" programme, co-funded by the European Commission's Directorate General for Energy and Transport, in the September 2007 - August 2013 period.

We assume at the start the principle – emerging in the recent sector literature – that the integration between local energy production technologies (district heating by gas cogeneration, photovoltaic, solar heating energy) is preferable to project solutions aimed at maximising recourse to specific energy generation technologies, viewed separately. An integration of sources which, we hope, can simultaneously ensure a simple management and control.

The potential offered by switching from the single building scale to the territorial sub-segment one in the simultaneous presence of several energy sources, highlighted by the results, certainly entails an increased degree of complexity, at the level of systems and at an evaluative level. Complexity that might lead, however, to important openings for territorial governance and the definition of policies compatible with the energy containment objectives and with the required performance requirements while being, at the same time, economically and financially sustainable.

1. INTRODUCTION

Currently, the redevelopment of the existing building stock, viewed within its territorial context, offers many openings involving, as we know, a particularly energy-hungry sector. Given that the rate of replacement of existing buildings with new buildings is only approximately 1-3% per year, a quick revamp of large scale retrofit measures is essential for a timely reduction in the global use of energy. It is moreover essential to reactivate the opportunities of investing in urban transformations which, eventually, might gradually change strategic areas of the cities, enabling the launch of processes of transformation to "smart cities": opportunities curbed as we know by the advent of the economic-financial crisis that has involved the property market and the construction sector [Brondino *et al*., 2011; Fregonara *et al*., 2017].

Due to this, defining the minimum energy requirements (Ministerial Decree No. 26/06/2015) with cost implications for new and existing buildings is a key aspect at European level. Thus it emerges from the international context of rules and policies for the energy-environmental sustainability of buildings, with significant impacts on the estimation and evaluation disciplines [Fregonara *et al*., 2016]. In particular, the analysis of the alternative project technologies shapes up as a crucial passage to verify the economic-environmental sustainability and thereby steer the choices of Public Administrations and private investors on investing in the retrofit of assets towards Energy-Efficient Buildings [Gluch *et at*., 2004; Schneiderova Heralova, 2014].

That said, the essay assumes the state of the art of theories and models for the economic assessment of the projects and, in relation to the international framework in the field of energy policies, it reconsiders it from a "technological-economic viewpoint". Firstly, we incorporate and develop some parts dealt with in the Laurea Magistrale Thesis in Architecture for the Sustainable Project, discussed at Politecnico di Torino by Omar Pasquarella in the 2015/2016 Academic Year, titled "Life Cycle Cost Analysis for the economic sustainability of new construction/energy retrofit interventions from building to district: the case of the "*Concerto AL Piano*" European project", Supervisor Elena Fregonara, Assistant Supervisor Corrado Carbonaro.

The focus is placed on the concept of "life cycle" incorporating objectives and principles of the Life Cycle Thinking [Glundes, 2016]: the life cycle is crucial for the decision-making processes in the presence of alternative technological options, on the different production/construction scales (single material, single component, building-plant scale systems) or at the different territorial levels (scale of complex transformation projects, district scale, urban scale) [Edwards *et al*., 2003; Caputo *et. al*., 2013; Ristimäki *et al*., 2013; Han *et al*., 2014]. In particular, the Life Cycle Costing (LCC), or Life Cycle Cost Analysis (LCCA) approach, is assumed as supporting tool for decisions between project alternatives in the presence of criteria of efficiency, effectiveness, short/long-term costs and benefits [Gluch *et at*., 2004]. Cornerstone of the LCC methodology (ISO 15686:2008 Standard – Part 5) is the concept of Global Cost (EN 15459:2007 Standard),which includes the energy costs of the buildings, the initial investments, and any residual value of the assets/components, compared to suitable annual discount rates.

The aim of the work is to test the LCCA approach on the district scale, transcending the more frequent applications developed on the building scale, already explored in the literature. Two are the expected levels of results: on the one hand, the replicability of the approach in the case of building complexes that are similar in terms of epoch, building type, construction characteristics, energy performance and, as it often happens, state of conservation; on the other hand, the extensibility of the LCCA approach from the individual building to urban territorial portions.

What is proposed is the simulation on a concrete case clarified by the European "Concerto AL Piano" project, developed as part of the "Concerto" programme, co-funded by the European Commission's Directorate General for Energy and Transport, in the September 2007 – August 2013 period. The "Concerto AL Piano" project, we should recall, assumed the goal of triggering urban regeneration processes on a building and district scale through the energy and environmental redevelopment of the existing fabric. By focusing on the "Cristo" district of the city of Alessandria, the project envisaged energy and architectural retrofit interventions on a residential complex owned by the Territorial Housing (ATC) of Alessandria, comprising 299 dwellings distributed across 11 residential buildings, a new residential complex called "new Eco-Village", made up of high energy-environmental sustainability apartments, a new Social Elderly (old-age home) owned by the ATC of Alessandria and the district heating network, powered by a gas cogeneration station [Pagani *et al*., 2016]. The more general aim of the project was to prove that urban regeneration, through energy retrofit and the construction of new high sustainability buildings, should have taken place through integrated interventions capable of uniting the technological implementation logic, on the building scale, to the energy infrastructure one, on the district scale.

From an economic viewpoint, the case is particularly interesting as it refers to a real context, which couples energy retrofit interventions on existing buildings with new construction interventions, enabling us to reason, as we said earlier, on the uban district scale and by comparison with different technological (and regulatory) approaches [Pagani *et al*., 2016].

That said, the aim of the research is to propose an operational method capable of:

- analysing different technological scenarios capable of meeting the energy performance requirements, with a view to identifying the preferable one in terms of economic sustainability;
- supporting the comparison between technological shapes limited to building scale equipment and interventions for shared energy infrastructure equipment on the district scale [Pagani *et al*., 2016].

More precisely, it intends exploring whether the interventions on the urban district scale can ensure, at an energy-economic level, the accomplishment of preferable solutions – in optimal-cost terms –, compared to building scale interventions. The extension in scope of application from building to district assumes moreover the potential advantages ensured by the replicability of the energy retrofit interventions on the existing building heritage, or in the case of large building operations that often intercept territorial sub-segments of homogeneous types and property value systems.

Given these premises, the essay is structured as follows: in section 1 we set out the reference regulatory framework on the topic. Section 2 is dedicated to the description of the application context, with regard to the chosen case-study. In section 3 we introduce the methodology, expressed as analysis of the expected energy consumption and economic analysis. In section 4 we illustrate the results of the energy-economic results. Section 5 concludes the writing.

2. REGULATORY FRAMEWORK

The crux of energy policies in the last decades lay, as we stated at the beginning, at the heart of the international political debate. In sinergy with it, the scientific communities involved proved especially active in supporting, through methodological and application contributions, the definition of the policies themselves or the adoption and transposition of EU regulatory guidelines into local standards. The synopsis of rules revolves around two essential European directives and some international Standards, sharing the objective of promoting improved energy performance of buildings and standardising the methodological guidelines aimed at supporting the practical action thereof.

Hereunder we mention the main standards taken as reference for the work herein presented:

- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), Off. J. Eur. Union (2010);
- Guidelines accompanying Commission Delegated Regulation (EU) no. 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council, Off. J. Eur. Union (2012) on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements;
- Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC;
- Standard ISO 15686:2008, Buildings and constructed assets – Service-life planning, particularly Part 5: Life Cycle Costing, prepared by Technical Committee ISO/TC 59, Building construction, Subcommittee SC 14, Design life;
- Standard EN 15643-4: 2011, Sustainability of construction works - Assessment of buildings - Part 4: Framework for the assessment of economic performance;
- Standard EN 16627:2015 - Sustainability of construction works. Assessment of economic performance of buildings - Calculation methods;
- Standard EN 15459:2007 - Energy performance of buildings - Economic evaluation procedure for energy systems in buildings.

3. EXPERIMENTATION CONTEXT

The “Concerto AL Piano” project stems from an initiative promoted by the European Commission. The title of “Concerto” was chosen in line with the idea that the suggested programmes envisaged participation by several social players to pursue ambitious objectives within urban transformation processes. The European programme, which involves 58 communities in 22 exemplary projects, aims to tackle, on an urban neighbourhood scale, the problems associated with the concept of sustainability with regard to the exploitation of renewable energy resources, given the objective of maximizing energy efficiency on the building and district scale.

Each Concert project tackles the complexity intrinsic to the urban transformation and regeneration processes, thanks to the deployment of multiple skills belonging to the world of the Public Administration, private investors and research. The experience of Concerto AL Piano has represented the opportunity to experiment the applicable “tactics” to accomplish the goal of energy sustainability on an urban scale: the integrated approach to urban planning finds its utmost meaning in the possibility of being strategically expanded and replicated in the cities. The generation of the Concerto projects has produced, within the technical directorates of the European Community, the experience necessary to move from the district scale to the city scale, taking stock of the Lessons Learnt and launching the new experimentation programme called “Smart Cities” [Mosannenzadeh *et al*., 2017].

The city of Alessandria, by taking part in the “Concerto” project, had the chance to understand the importance of strategically planning the use of energy resources on an urban scale, fuelling new partnerships between public and private subjects and a more far-reaching know-how backed up by the discussion with other European realities and research contexts. The experience was in fact the starting point of a process that eventually led to subscribing the Covenant of Mayors. The latter, as we know, consists in an initiative of the European Community that involves cities in the development of Strategic Energy Action Plans, i.e. urban energy management plans, given the objective of reaching a 20% decrease in CO_2 emissions by 2020.

The “Concerto AL Piano” project area, already involved by a schedule of interventions envisaged by the District II Contract, is exemplary as a portion with large urban voids and with significant social integration problems, urban and building decay and lack of services. The area in question is one of the many voids present in the urban periphery, an interstice between social housing plots, built without any integration with the existing. A quick reading of the territory evinces the breaks that compromise the urban fabric, the voids that characterise its discontinuity, and the old territorial matrices (from farmsteads to urban fortifications), still visible but denied by the post-World War II divisions.

The project puts forward solutions capable of remedying problems in fragmented and degraded urban contexts with a correct redevelopment of the existing, promoting a broader social diversity, building new houses and services and equipping infrastructures for exploiting renewable energy sources, thereby regenerating the urban fabric.

Lastly, the European "Concert" project enabled local institutions to render the urban regeneration project more ambitious, thanks to the possibility of relying on the expertise and skills of the European partners involved and to the further incentives for energy sustainability on the district and building scale, based on the exploitation of renewable sources.

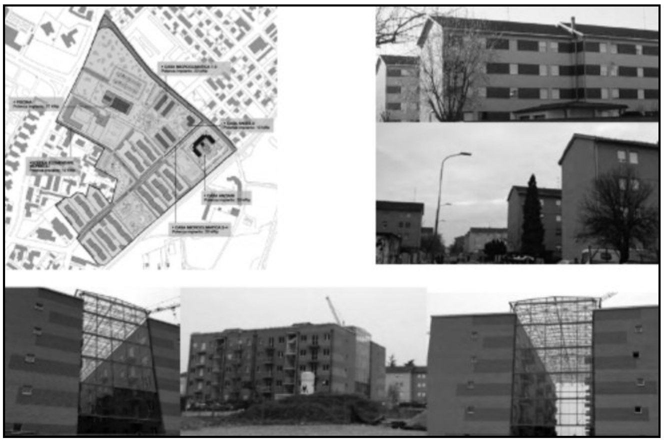

Figure 1 - *"Concerto AL Piano" project area. Renew: public housing buildings before and after retrofit. New: micro-climatic houses*

More precisely, the project envisages an integrated approach to planning, shared by all the stakeholders (municipality, professionals, institutions, inhabitants, companies), with interventions both on a building scale, implementing its enclosure and heating system equipment, and on a district scale, through the creation of a new "Distric Heating" powered by a methane cogeneration station. Such a project choice stems from the intention typical of the projects within the Concert programme: ascertaining the economic and energy convenience of distributed energy generation, with local district-based cogeneration stations powered by renewable sources. The experiments of the last decade suggest in fact that widespread generation can yield advantages both in economic terms and in terms of global efficiency of the urban energy system [Manfren *et al.*, 2011; Martin-Martinez *et al.*, 2017].

In the energy simulations developed within the scope of the project, solutions have been identified that, though sharing the principles of a multiple-scale planning, were able to maximize mutually alternative technological configurations. The range of solutions, on a territorial scale, discloses energy performances from class F to class A4, as per the classification set out in Ministerial Decree No. 26/06/2015 on minimum energy requirements of buildings.

At a strategic level, an urban regeneration programme has been developed that we could sum up under four essential points:

- Participatory planning for the identification of shared objectives and communication of the results accomplished;
- Planning with analysis methods of the energy-environmental sustainability, with a view to checking and simulating the results of project choices;
- Recourse to integrated technological systems and efficient and uncommon architectural types, to ensure high performances within the scope of energy sustainability and housing comfort;
- Verification and monitoring of the results to validate the methods to replicate in other parts of the city and eventually intervene should the need arise to implement the results.

On a tactical level, the project contemplates instead the implementation of three lines of intervention:

- New – construction of new residential eco-buildings and a new district heating network, powered by a cogeneration station for a total of 104 dwellings;
- Re-New – redevelopment of a social housing complex with 300 dwellings owned by the Territorial Housing Agency of the Province of Alessandria (ATC);
- New Social Elderly – creation of a new old-age home by the ATC of Alessandria, to host a community of elders in a low energy consumption residential building;
- Retrofit – promotion of energy redevelopment interventions on a vast urban area of Alessandria, for the purposes of spreading the culture of sustainability, obtaining widespread information on building quality and the technological equipment of the urban fabric, and developing a macro-scale intervention strategy pursuant to the energy model built on the strength of the feedback received by the redevelopment action.

4. METHODOLOGICAL FRAMEWORK

The main body of the study is founded on a two-phase analysis: 1) analysis of the expected energy consumption; 2) economic analysis. More precisely, the results of phase 1) converge, as input data, into phase 2).

At the end of phase 2), the final solutions are highlighted, in terms of preferable solutions from an energy-economic viewpoint.

Phase 1) – assessment of the expected energy consumption, revolves in turn around the following passages:

- identification of energy-efficient solutions to improve the energy performance of the enclosure of buildings and the building-plant system by improving the enclosure components, the connection to the district heating network and the equipment of plants for the production of energy from renewable sources;
- definition of different scenarios based on combinations of mutually alternative technological solutions;
- calculation of primary energy consumption for each scenario, following calculation of requirements for winter air-conditioning, production of domestic hot water and electricity for domestic use;
- comparison of the technological scenarios in relation to the relevant expected energy consumption.

Phase 2) - economic assessment, revolves in turn around the following passages:

- calculation of the Life Cycle Cost for each scenario, in terms of Global Cost, hence in respect of the entire lifecycle of the buildings and incorporating the results of the analysis of expected energy consumption;
- calculation of the economic performance indices through the Life Cycle Cost Analysis approach;
- comparison of the economic indicators of the alternative scenarios to the "basic scenario";
- identification of critical variables and development of the Sensitivity Analysis (deterministics);
- identification of the preferable solution from both an energy and an economic viewpoint.

Hereunder recalled are some detailed methodological aspects.

4.1 Analysis of energy consumption: methodological aspects

We can summarise the methodology adopted for the analysis of actual energy consumption of the existing systems and for the analysis of the forecast energy consumption of newly constructed buildings in the following points:

- the primary energy consumption of existing buildings, both preceding and following the retrofit interventions, are quantified pursuant to the electricity and heating consumption drawn from the bills issued by the ATC of Alessandria for the 2006-2012 period;
- the primary energy consumption of newly constructed buildings (New Eco Village and New Social Elderly) is calculated via simulations produced using the TERMUS software (produced and distributed by ACCA software S.p.A.), in conformity with the UNI EN ISO 11300 standard - part 1;
- the expected consumption figures relating to the electricity and heating production plants using renewable sources are calculated through the TERMUS software in accordance with the UNI EN ISO 11300 standards - parts 4 and 5;
- calculation of energy production from cogeneration and heating and electricity distribution plant is carried out pursuant to simulations performed by the company in charge of the district heating network project in the 2011 version, conciding with an 86.5% first-law performance, 39.6% of the total of which is dedicated to the production of electricity (work not implemented and replaced pursuant to the project produced by another company providing energy services);
- calculation of the primary energy input due to the presence of solar greenhouses is done by using the TERMUS software, in conformity with the UNI EN ISO 11300 standard - part 1;
- the analysis of thermal energy saved as a result of exploiting the solar Atrium technology is simulated considering, in the phase of energy budget of the buildings, the walls facing the micro-climatic atrium and facing unheated rooms pursuant to the UNI EN ISO 11300 standard - part 1;
- the value adopted for the heat losses due to dispersions of the district heating network is equal to 10%, in relation to the indications provided by the report headed "Fact-finding investigation on the district heating sector (IC 46)";
- the value adopted for the dispersions due to the distribution and transport of electricity produced by the cogenerator coincides with that of the small distribution networks: 2,2 % (Source: Electricity and Gas Authority);
- in case of electricity collection directly from the national grid, we took into account a 0.413, performance in view of the amount of generation, distribution and transport inefficiencies;
- the input data relating to heating conductivity, vapour permeability and density of envelope materials are drawn from the technical data sheets of the materials adopted in the building interventions, whereas for the existing walls they are assumed in relation to the database of the TERMUS software, consistently with the UNI EN ISO 1600 standard - part 1.

4.2 Economic analysis: methodological aspects

From an economic viewpoint, we propose application of the LCCA approach, whose methodological foundation can be traced, as we mentioned, in the ISO 15686-5:2008 Standard - Buildings and constructed assets – Service-life planning (document drawn up by the ISO/TC 59 Technical Committee, Building construction, Subcommittee SC 14, Design life). We assume in particular the methodology set out in Part 5 - Life Cycle Costing.

As we know, the approach is used to quantify and compare alternative project proposals, in terms of costs and potential savings, viewed in respect of the entire life cycle and in respect of significant cost categories (Flanagan, 1983; Schmidt, 2003; Fregonara *et al.*, 2017 a,b). Usually, in the real estate intervention projects one compares through the LCCA approach, pursuant to efficiency and effectiveness criteria, various technological solutions that might be referred to single components, single materials, systems or whole buildings. It is then useful to remember that the approach is suitable for dealing with both new construction interventions and energy adjustment /retrofit interventions on existing buildings, including the case of historic assets. The general purpose of the method is in fact to compare solutions on the basis of the relevant costs in the life cycle, or to define preferability rankings between mutually alternative projects.

In the recent literature we can trace applications that pay regard to systems on the building scale (for instance, lighting, heating-cooling, hot water production systems), focusing on the quantification of short- or long-term costs and potentially produced benefits (usually in the form of savings, or "negative costs").

The results are normally expressed through the calculation of such quantitative indicators as: Net Present Value (NPV), Net Present Cost (NPC), Net Savings (NS), Simple/ Discounted Pay Back Period (SPB/DPB), Savings to Investment Ratio (SIR), and Adjusted Internal Rate of Return (AIRR). Of essence to the calculation is the prior availability of input data on the significant costs, on the cost profiles of each option, and of financial data (Langdon, 2007; König *et al.*, 2010).

The heart of the LCCA method is calculation of the Global Cost as per the terms defined in the EN 15459:2007 Standard, later specified in the relevant Guidelines and in the Commission Delegated Regulation (EU) No. 244/2012, issued pursuant to Directive 2010/31/EU – EPBD recast. As is known, calculation of the Global Cost traces us back to two possible approaches: the global cost method and the annuity method. The former is here proposed by analogy with the consolidated methods for assessing the economic feasibility of the projects (particularly with the Discounted Cash-flow Analysis approach which, like the LCCA approach, evinces a calculation formulation based on discounted cash flows).

Formally, as recalled in recent studies (Corrado *et al.*, 2014; Becchio *et al.*, 2015) the Global Cost envisages the sum of the initial investment costs (not discounted), to which we should then add the sum of the annual costs incurred during the exercise of the asset, within the reference time span (useful life), after deducting the final residual values, all of them discounted. The final residual values can be present where the systems/components disclose a longer useful life than the whole building. Formally, the generated model proves to be as follows [EN 15459:2007]:

$$C_G(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \cdot R_d(i)\right) - V_{f,\tau}(j)\right]$$

where: $C_{G(\tau)}$ = global cost (referred to the initial year τ_0); C_I = initial investment costs; $C_{a,i\,(j)}$ = annual cost in the year i of component j, which includes the annual operating costs (costs for energy, operating costs, maintenance costs) and periodic replacement costs; $R_{d\,(i)}$ = discount factor during the year i; $V_{f,\tau(j)}$ = residual value of component j at the end of the calculation period, referred to the initial year. The costs must be suitably analysed, as they refer to the entire calculation period; formally, the R_d discount factor looks like:

$$R_d(p) = \left(\frac{1}{1 + \frac{r}{100}}\right)^p$$

where: p is the number of years and r represents the real discount rate, defined in relation to the territorial context in which the analysis is situated.

In a nutshell, calculation of the Global Cost proposed in this study is founded on the following assumptions:

- to perform the calculation, we adopt the "global cost method" (alternative to the annuity method);
- the initial investment costs relate to the new construction/retrofit interventions prefigured in accordance with different technological scenarios. In particular, for the existing buildings account is taken of the costs of energy retrofit through heating systems and technological implementation envelope measures; for the new buildings, regard is paid to the construction costs;
- account is taken, among the significant costs, of the operating and maintenance costs;
- (any) residual value of the assets/systems/components/ materials and the end-of-life/disposal costs are not taken into consideration.

Formally, calculation of the global cost – simplified here compared to the generalised model and without considering, moreover, any residual value of the assets/systems/components/materials and the end-of-life/disposal costs - revolves around the following equation:

$$LCC = C_i + \sum_{t=0}^{N} \frac{C_0 + C_m}{(1+r)^t}$$

where: LCC represents the cost in the life cycle; C_i represents the initial investment costs; C_o represents the operating and energy (or management) costs; C_m represents the maintenance costs, t the year in which the costs arise and N the number of years included within the timespan taken into account for the application; and r represents the discounting rate.

It should be noted that the input data relating to the significant cost items are usually inferred from market analyses, by comparison with similar interventions, or from pre-established databases, or even from investigations conducted among fiduciary sources (sector operators). The choice of reference timeframe for the calculation – being a very delicate passage – is made pursuant to the estimated life of the building and its technological components· Some indications on the lifespans, of systems and components as well, can be inferred from the guidelines set out in the document headed Commission Delegated Regulation (EU) No. 244/2012, in addition to the European Standard EN 15459:2007 (Annex A).

Moving from the premise of these methodological assumptions, we set the aim of identifying the preferability ranking of a set of scenarios, predefined in relation to different technological solutions, or Energy Efficiency Measures (EEMs), by developing the economic analysis set out in section 4.

5. ANALYSIS OF EXPECTED ENERGY CONSUMPTION AND ECONOMIC ANALYSIS

As mentioned earlier, to apply the LCC analysis we must possess data on the energy performance of the buildings in relation to alternative scenarios (EEMs), a prerequisite that each technology included in the project solutions implies different costs and different performance levels; out of these scenarios, we will have to select the preferable solution, or the relevant preferability ranking in economic and energy terms.

5.1 Analysis of energy consumption: application

The analysis of the expected energy consumption is produced starting from the prefiguration of 6 scenarios obtained by distinguishing, as regards each one of them, the portion of new construction/retrofit and by identifying the relevant EEMs. The latter are expressed on the strength of different technological implementation approaches on a building and on a district scale: envelope system, installation system, infrastructural and energy equipment servicing the urban area under examination. The analysis carried out does not take into account the New Social Elderly intervention, as we are not in possession of all the data relating to the costs incurred for the construction of the building.

Accordingly, the cost referred to the creation of the cogeneration plant and district heating network has been parameterised on the basis of the areas actually used in the analysis of the scenarios under investigation.

The simulations on the expected consumption levels of the 6 scenarios are carried out in respect of the performance requirements prescribed by the reference legislation (Regional Council Decree No. 43-46/2009, Ministerial Decree No. 26/06/2015, prescriptions until 2021), in respect of the factual state and of the project indications.

The various scenarios differ, by comparison, from the intervention concretely implemented in the ”Concerto AL Piano” project (called Scenario 3), according to the following envelope and plant technological strategies:

- the state of affairs prior to the completed retrofit interventions with the estimated assessment of energy consumption for the New Eco-Village, as if it had been built according to the limits enjoined by the 2009 regional legislation (Regional Council Decrees 43 and 46 of 2009) (Scenario 1);
- the “Concert AT THE Plan” project, reconsidered in the condition in which the buildings have envelope-related thermal transmittance values in line with the 2009 reference regulatory framework and for which the thermal and electrical energy is supplied by the cogeneration district station, supplemented by the one self-produced on the newly constructed buildings that cover, respectively, 60% of the expected energy requirement for hot water and 31% of the electricity requirement (Scenario 2);
- the “Concerto AL Piano” project, modified in such a manner that the buildings have envelope-related thermal transmittance values in line with the limits set until 2021 (Ministerial Decree of 26/06/2015), to thereby maximise the generation of energy on a building scale (eliminating any district-based technological and energy integration strategy) and ensure that the energy requirement is fully met thanks to the production of energy from a solar source backed up by condensing boiler (for the peak in demand and as back-up), storage system and control and management unit (Scenario 4);
- the project in all respects similar to Scenario 4 except for the technological envelope equipment, in this case identical to that concretely implemented in “Concerto AL Piano” (Scenario 5);
- the “borderline” design structure, which adopts the technological integration strategy on a district scale by resorting to the use of absorption surfaces for solar technologies of the common and public areas servicing the buildings in the intervention area, maximising the use of photovoltaic energy on the building scale, combined with a thermal plant with air-water heat pumps, and equipping the buildings with envelope technologies identical to those actually implemented in the European project (Scenario 6).

The alternative scenarios are thus compared with Scenario 3, taken as base-case.

Scenarios 4, 5 e 6 are characterised by the maximisation of solar technologies, which require a very extensive absorption surface. The choice of adopting such scenarios is made in order to ascertain what is economically preferable, the adoption of a technology in which costs are largely supported by forms of State funding that directly impinge on the ownership of the property (65% of the investment cost can be deducted tax-wise in 10 annual instalments according to Law No. 205 of 27/12/2017). Maximisation of the absorption surface certainly demands a very extensive quantity of well-exposed absorption surface, which in the case of Scenario 6 consists in 6650 m^2 of photovoltaic panels.

Aware of the difficulty that application of such energy measure entails, especially in an urban area, albeit one equipped with abundant green spaces, the choice was taken to operate in that sense in order to represent a "borderline case" of systemic approach to energy-environmental design on a district scale. It should be noted that, realisticlly, it would be necessary to enter beforeand into specific agreements with the public institutions with a view to placing platform roofs and canopies in the green spaces acting as support to the generation of private energy: the private subjects, by donating a share of the tax deductions, would pay for the occupation of the exposed surfaces of the platform roofs whilst retaining the advantage of an energy generation from renewable source that is nevertheless economically convenient. The local government would instead be able to subsidise, at least in part, the creation of small urban infrastructures (platform roofs, canopies, small buildings for the management and maintenance of the public spaces) by virtue of the sale of the covered areas with the best solar exposure.

Through the TERMUS programme for energy certifications, consumption data corresponding to the 6 different intervention scenarios have been identified.

As evinced by Figure 2, the primary energy consumption level progressively decreases the more technological solutions on a building scale are integrated with energy production measures on the district scale. Especially for renewable sources, the need for useful, sunny and not shaded space is not always available on the roofs and facades of the buildings: the possibility of resorting to common surfaces, which implement production, proves to be the most convenient from an energy viewpoint.

Consistently, the different performances of the analysed scenarios correspond to different Energy Classes, as evinced by Figure 2.

By comparing the results of the simulation of primary energy consumption for winter air conditioning, for hot water consumption and electricity production for domestic use, it is clear that:

- the comparison between the project area consumption before and after the "Concerto AL Piano" project (Scenario 1 vs. Scenario 3) highlights the fact that the selected technological measures are especially effective for the retrofit intervention of the ATC residential complex, for which we obtain an approximate 60% reduction in consumption levels that causes the energy class D to be reached, whereas for the New Eco Village the reduced difference of enclosure solutions and the switch from a standard hot water heater (2009 standard) to the district heating network entails little more than the jump of one energy class (13% decrease in expected primary energy consumption);
- the comparison between Scenario 2 and Scenario 3 highlights the fact that for the new constructions the Concerto AL Piano solutions yield results that are 5% better than legal prescriptions for 2021, by virtue of the superior technological enclosure equipment, whereas for the retrofit the interventions of isolation and replacement of doors and windows in Scenario 2 occasion a 36% decrease in expected primary energy consumption;
- the comparison between Scenarios 4 and 5 shows that, where the plant equipment is the same, the project that resorts to more efficient dispersion-containment measures obviously achieves a better result; such a comparison further underlines that, as widely reported in the scientific literature [Mancarella, 2014], the most effective intervention is characterised by an integrated implementation capable of involving the whole building-plant system (and not just one of the two);
- since the energy classification method applied to buildings does not take into account the primary energy consumption met by a renewable source, Scenario 5, which envisages equal enclosure technologies while maximising recourse to solar energy sources in lieu of gas cogeneration sources, albeit highly effective, proves to be preferable to Scenario 3 as regards both new interventions (42% decrease in expected primary energy consumption) and redevelopment interventions (59% decrease in expected consumption);
- the comparison between the three scenarios that use only solar energy sees Scenario 6 as the most sustainable one energy-wise, inasmuch as it exploits more efficiently, for the thermal energy part, the photovoltaic electricity, produced thanks to the coupling with a high-efficiency air-water heat pump (Coefficient of Performance > 4).

Assessment of the energy budget of the district targeted by intervention highlights the fact that on an urban sector scale it is important to develop projects that seek to simultaneously ensure fulfilment of the following three conditions:

1. integrated assessment of the entire building-plant system and not only of the enclosure or the heating and electricity systems;
2. maximised use of renewable sources;
3. widespread energy generation by integrating the building-scale production systems with district-scale ones, through the exploitation, agreed with local institutions, of common furnishings and equipment for widespread energy generation (such as the covering of platform roofs facing south).

The implementation of widespread infrastructures (solar systems for energy production) or concentrated ones (cogeneration stations with district heating network) servicing the district occasions, moreover, the possibility of reducing the marginal expenditure costs for energy. In this connection, we can assume that if the community organised itself as a "single user" for the supply of energy relating to the urban area of transformation (for instance as a local consumer association), it would no doubt possess greater contractual strength vis-à-vis energy service providers, thereby deriving greater economic benefits.

5.2 Economic analysis: application

The aim of the economic analysis is to compare the aforementioned alternative technological scenarios, with a

Table 1 - *Intervention scenarios*

SIMULATIONS AND ANALYSIS OF THE RESULTS:
PROJECT SCENARIOS

		TECHNOLOGICAL INTEGRATION AT THE NEIGHBORHOOD LEVEL	REFERNCE OF BUILDING ENVELOPE TRASMITTANCE	LOW EFFICIENCY BOILER (ng = 0,65)	(U : W/mqK)			(U : W/mqK)	CONDENSING BOILER (ng = 0,85)	HEAT PUMPS FOR HEATING AND DHW	BASIC BOILER (ng = 0,75)	COGENERATION SYSTEM	NATIONAL ELECTRIC SYSTEM	SOLAR THERMAL SYSTEM	PHOTOVOLTAIC SYSTEM
ENERGY SOURCE				NATURAL GAS					NATURAL GAS	SOLAR POWER BY PV	NATURAL GAS	NATURAL GAS	MIXED ENERGY SOURCE (national energy mix)	SOLAR POWER	SOLAR POWER
- SCENARIO 1	NEW	NO	D.G.R. 42-46/2009	----	0.30	0.33	0.33	2.00	100% heating and 40% DHW demand	----	60% DHW demand	----	Domestic use only	60% DHW demand	----
	RE-NEW		BEFORE REFURBISHMENT (2009)	100% heating and DHW demand	(1.00)	(0.92)	(1.50)	2.00	----	----	----	----	Domestic use only	----	----
- SCENARIO 2	NEW	YES District energy cogeneration CHP and solar technologies	D.M. 26/06/2015 MINIMUM REGULATORY VALUES FROM 2021	----	0.26	0.26	0.22	1.40	----	----	----	remaining shares of H., DHW and El. demand	----	60% DHW demand	31% El. demand
	RE-NEW											100% El and DHW demands	----		
- SCENARIO 3	NEW	YES District energy cogeneration CHP and solar technologies	CONCERTO AL PIANO VALUES	----	0.22	0.21	0.20	1.60	----	----	----	remaining shares of H., DHW and El. demand	----	60% DHW demand	31% El. demand
	RE-NEW				0.29	(0.92)	0.32	2.00				100% El and DHW demands	----	----	----
- SCENARIO 4	NEW	YES Solar technologies on public neighborhood surface	D.M. 26/06/2015 MINIMUM REGULATORY VALUES FROM 2021	----	0.26	0.26	0.22	1.40	For peaks demand and back - up	----	----	----	----	100% heating and DHW demand	100% El. demand
	RE-NEW														
- SCENARIO 5	NEW	YES Solar technologies on public neighborhood surface	CONCERTO AL PIANO VALUES	----	0.22	0.21	0.20	1.60	For peaks demand and back - up	----	----	----	----	100% heating and DHW demand	100% El. demand
	RE-NEW				0.29	(0.92)	0.32	2.00							
- SCENARIO 6	NEW	YES Solar technologies on public neighborhood surface	CONCERTO AL PIANO VALUES	----	0.22	0.21	0.20	1.60	----	100% heating and DHW demand	----	----	----	----	100% El. demand of Heat pumps
	RE-NEW				0.29	(0.92)	0.32	2.00							

* H. = Heating E. = Electicity DHW = Domestic Hot Water

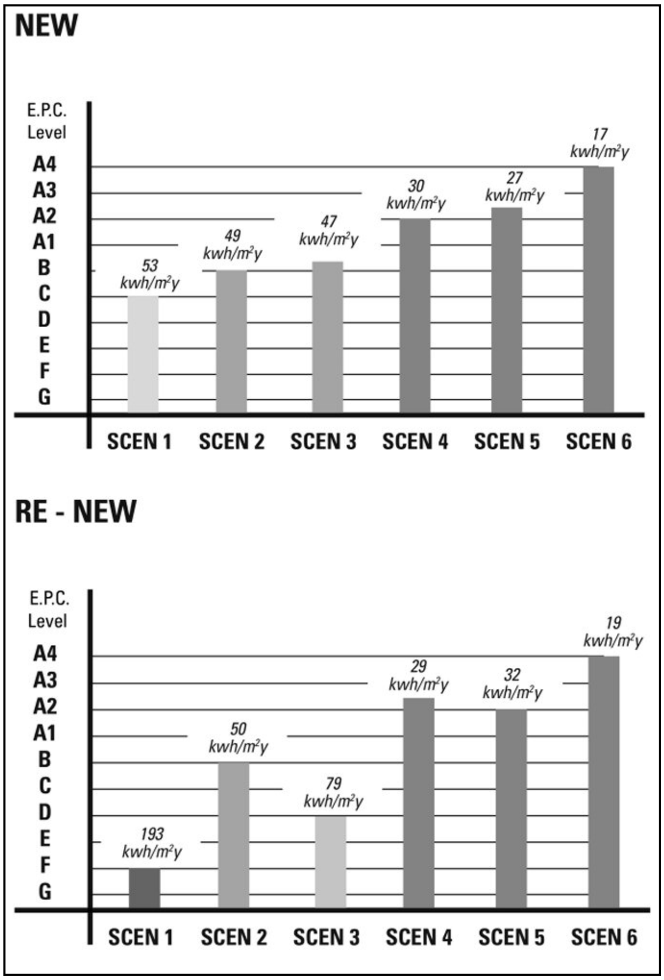

Figure 2 - *Energy performance of the intervention Scenarios*

view to supporting the definition of technological design strategies on a district scale, assuming two starting premises:

1. ensuring the comparability between all the scenarios by retaining the characteristics of the implemented "Concerto AL Piano" project, as developed within a single context;
2. updating the construction, plant and management costs, in order to provide as current a project framework as possible.

The first condition is ensured through maintenance for all the scenarios of the same types of intervention, modifying only some technological enclosure or plant equipment. Moreover, to avoid altering the economic context within which the "Concerto AL Piano" project was developed, across all the scenarios the framework of tax deductions and incentives resulting from national standards and from the funds coming from the European Union was retained. The projects of the European "Concerto" programme, in fact, envisaged incentives equalling 30% of the costs incurred for the energy efficiency measures relating to:

- enclosures of existing or newly constructed buildings,
- energy generation plants using renewable sources;
- district heating networks powered by cogeneration stations on the district scale fuelled by renewable sources (mainly biomass).

In the case, therefore, of the "Concert AT THE Plan", the cogeneration intervention and the related district heating network cannot be the recipient of European funding since the station set up is powered by methane gas rather than biomass.

The other incentive items taken into account in the economic analysis relate to the IRPEF (Income Tax on Natural Persons, pursuant to Law No. 205 of 27/12/2017) tax defuctions which, concerning the "Concerto AL Piano" project, can be summarised as follows:

- 65% tax deductions for energy production plants powered by renewable source, as regards both retrofit and new construction;
- 65% tax deductions of the costs of restructuring interventions to render the enclosure efficient and replace the heating and hot water production plants;
- 50% tax deductions of the costs incurred for the

restructuring and ordinary maintenance interventions not ascribable to interventions to implement the energy efficiency of the building.

The second condition, relating to the updating of intervention costs, is guaranteed through the prompt identification of all the restructuring and construction costs for the residential buildings and the energy plants of the project as set out in Table 2. The construction and retrofit costs of the buildings are deducted from estimated meter calculations relating to the executive projects. The values recorded date back to the period between 2009 and 2013, later discounted pursuant to the

average inflation rate for the 2009-2017 period made equal to 1.13% (source: ISTAT). As set out in Table 2, some cost items are instead updated to the last two-year period, in relation to current average prices.

The updating of the costs has accordingly involved the following items:

- costs for the photovoltaic panels, affected by a significant drop especially as regards supply;
- plant maintenance costs;
- costs for the heating system, not envisaged in the project implemented in Concerto AL Piano" (heat pumps, condensing boilers, thermal energy management and storage systems).

The updating process concerns also the cost of thermal energy and electricity, whose value chosen for the analysis coincides with the values provided by Regulatory Authority for Energy Networks and Environment - ARERA, as at 2018.

The economic analysis, in fact, besides the construction cost, includes also the ordinary and extraordinary maintenance costs, as well as the costs relating to energy supply over a 20-year time span, adopted as temporal horizon.

Pursuant to the methodological indications of the ISO 15686-5:2008 standard, the "significant" cost items and the related data, set out in Table 2, have been identified for the LCCA application.

Operationally speaking, the LCCA application was performed through calculation of the Global Cost and calculation of the economic performance indicators envisaged by the model; in particular, the following have been calculated: Net Present Value – NPV, Pay-Back Period Simple/Discounted – SPB/DPB, Savings to Investment Ratio – and SIR, Adjusted Internal Rate of Return – AIRR.

The following financial input data have been assumed for the analysis:

- the discount rate, assumed to be equal to 2.5% defined in relation to the investment-linked risk. The risk is deemed to be quite moderate by virtue of such considerations as the specific market in which the intervention is located, the potential savings generated by the retrofit interventions, the tax deductions, and the exploitation of the assets;
- the time span covered by the analysis made equal to 20

Table 2 - *"Relevant" costs per Scenarios: investment, operating and management costs*

SUPPLY, PROVISION, INSTALLATION AND MANAGEMENT COSTS COMMON TO NEW E RENEW PROJECTS		
TYPE OF DATA	COST	REFERENCES
ELECTRIC POWER SUPPLY	0,25 €/KWh	ARERA 1° quarter 2018 (daily single rate)
HEATING AND DHW SUPPLY	0,11 €/KWh	ARERA 1° quarter 2018
PHOTOVOLTAIC PROVISION AND INSTALLATION	2420 €/Kwp	Energia.it (April 2017 data)
SOLAR THERMAL PROVISION AND INSTALLATION	1795 €/m^2	Concerto AL Piano data (2014)
District energy cogeneration CHP (Including costs for the heating district network)	2.361.972 €	Concerto AL Piano data (2014)
District heating network costs	668 €/m	Piedmont regional price list for public works (2016)
HEAT PUMP PROVISION AND INSTALLATION Heat exchanger 350 kw + water storage tank 470 l.	9.485 €	Piedmont regional price list for public works (2016)
COGENERATION SYSTEM MAINTENANCE	8 €/Mwh	Confindustria.it (April 2017 data)
SOLAR TEHRMAL SYSTEM MAINTENANCE	15 €/m^2	Confindustria.it (April 2017 data)
PV SYSTEM MAINTENANCE	40 €/Kwp	Confindustria.it (April 2017 data)
COAT INSULATION PROVISION AND INSTALLATION (wood fiber)	25 €/m^2	Concerto AL Piano data (2014)
PROVISION AND INSTALLATION OF ROOF SPACE INSULATION (EPS)	18 €/m^2	Concerto AL Piano data (2014)
PROVISION AND INSTALLATION OF FIRTS FLOOR INSULATON (EPS)	13 €/m^2	Concerto AL Piano data (2014)
WINDOWS SYSTEMS PROVISION AND INSTALLATION (U:2 W/mqk)	330 €/m^2	Concerto AL Piano data (2014)
WINDOWS SYSTEMS PROVISION AND INSTALLATION (U:1,6 W/mqk)	400 €/m^2	Concerto AL Piano data (2014)

PROVISION AND INSTALLATION COSTS OF NEW ECO-VILLAGE (NEW)		
GENERAL INTERVENTIONS	€	REFERENCES
CONSTRUCTION WORKS		Concerto AL Piano data (2014)
PROVISION AND INSTALLATION BUILDING TECHNOLOGY SYSTEMS		Concerto AL Piano data (2014)
OUTDOOR ACCOMODATION WORKS		Concerto AL Piano data (2014)
PASSIVE SYSTEMS (GREENHOUSES AND ATRIUM)		Concerto AL Piano data (2014)
WORKS AND EQUIPMENT FOR ECOLOGICAL ISLAND PLATFORM		Concerto AL Piano data (2014)
DESIGN ACTIVITIES	5% of construction costs	
incentives taken into account in the simulation	%	REFERENCES
BUILDING RENOVATION WORKS	-	Law No. n° 205 of 27/12/2017
HEATING SYSTEMS REPLACEMENT (PROVISION AND INSTALLATION)	-	Law No. n° 205 of 27/12/2018
THERMAL SOLAR SYSTEMS (PROVISION AND INSTALLATION)	65	Law No. n° 205 of 27/12/2019
ENVELOPE RETROFIT WITH APPLICATION OF HIGH EFFICIENCY SYSTEMS	-	Law No. n° 205 of 27/12/2020

RETROFITTING COSTS OF ATC RESIDENTIAL COMPLEX (RENEW)		
GENERAL INTERVENTIONS	€	REFERENCES
CONSTRUCTION WORKS		Concerto AL Piano data (2014)
PROVISION AND INSTALLATION BUILDING TECHNOLOGY SYSTEMS		Concerto AL Piano data (2014)
OUTDOOR ACCOMODATION WORKS		Concerto AL Piano data (2014)
PASSIVE SYSTEMS (GREENHOUSES AND ATRIUM)		Concerto AL Piano data (2014)
WORKS AND EQUIPMENT FOR ECOLOGICAL ISLAND PLATFORM		Concerto AL Piano data (2014)
DESIGN ACTIVITIES	5% of construction costs	
incentives taken into account in the simulation	%	REFERENCES
BUILDING RENOVATION WORKS	50	Law No. n° 205 of 27/12/2017
HEATING SYSTEMS REPLACEMENT (PROVISION AND INSTALLATION)	50	Law No. n° 205 of 27/12/2018
THERMAL SOLAR SYSTEMS (PROVISION AND INSTALLATION)	65	Law No. n° 205 of 27/12/2019
ENVELOPE RETROFIT WITH APPLICATION OF HIGH EFFICIENCY SYSTEMS	65	Law No. n° 205 of 27/12/2020

years, given the life span of the technological element of shortest duration included in the intervention project (photovoltaic/solar heating system).

Moreover, we assume Scenario 1 as basic comparison scenario inasmuch as, for the same, no retrofit interventions on the existing buildings are contemplated but only the mere construction of new buildings pursuant to the regulatory prescriptions laid down in Regional Council Decrees 43 and 46 of 2009. Due to this, in the comments set out hereunder no regard is paid to Scenario 1. For the same reasons, we assume the omission from the illustration of results of the the Net Savings (NS) indicator, since the same is calculated as difference between the "LCC base-case" application and the "LCC comparison case" application, for each Scenario: if the base-case, as in this application, does not envisage comparable intervention measures, the indicator proves not to be significant.

The values obtained by calculating the indicators have been summarised in Table 3, with a special focus on the acceptability conditions for each indicator.

Table 3 - *Summarised results of the LCC Analysis. Economic performance indicators*

	NPV (Global Cost) (Euro)	SIR	AIRR	SPB (Year)	DPB (Year)
Feasibility conditions	As low as possible	accettable > 1 non accett. < 1	accettable > 2,5% non accett. < 2,5%	As low as possible	
Scenario 2	48543323	1.63	5.0%	8	9
Scenario 3	48109799	1.76	5.4%	7	8.5
Scenario 4	51003631	1.51	4.6%	8.5	10
Scenario 5	50138844	0.40	4.2%	9	11
Scenario 6	42899117	2.23	6.7%	6	7

In Figure 3, we show the results in graphical form including, for the sake of completeness, the graph of the calculated comparative SPBP trends.

A reading of Table 3 and Figure 3 lends preference to Scenario 6 that anticipates, let us remember, envelope characteristics of the immovable properties similar to those of Scenario 3, but with a plant system capable of totally meeting the energy requirement through photovoltaic solar panels. The Net Present Value (NPV) is in fact the lowest possible one compared to the comparable Scenarios assuming a value of EUR 42899117; the Savings to additional Investment Ratio (SIR) is > 1, in particular 2.23; the Adjusted Internal Rate of rRturn (AIRR) value is higher than the discount rate applied for calculation of the NPV (2.5%), assuming a 6.7% value. Moreover, the Simple Pay-Back period (SPB), calculated through the cumulated flow, proves to be comparatively the shortest (6 years, discounted 7 years).

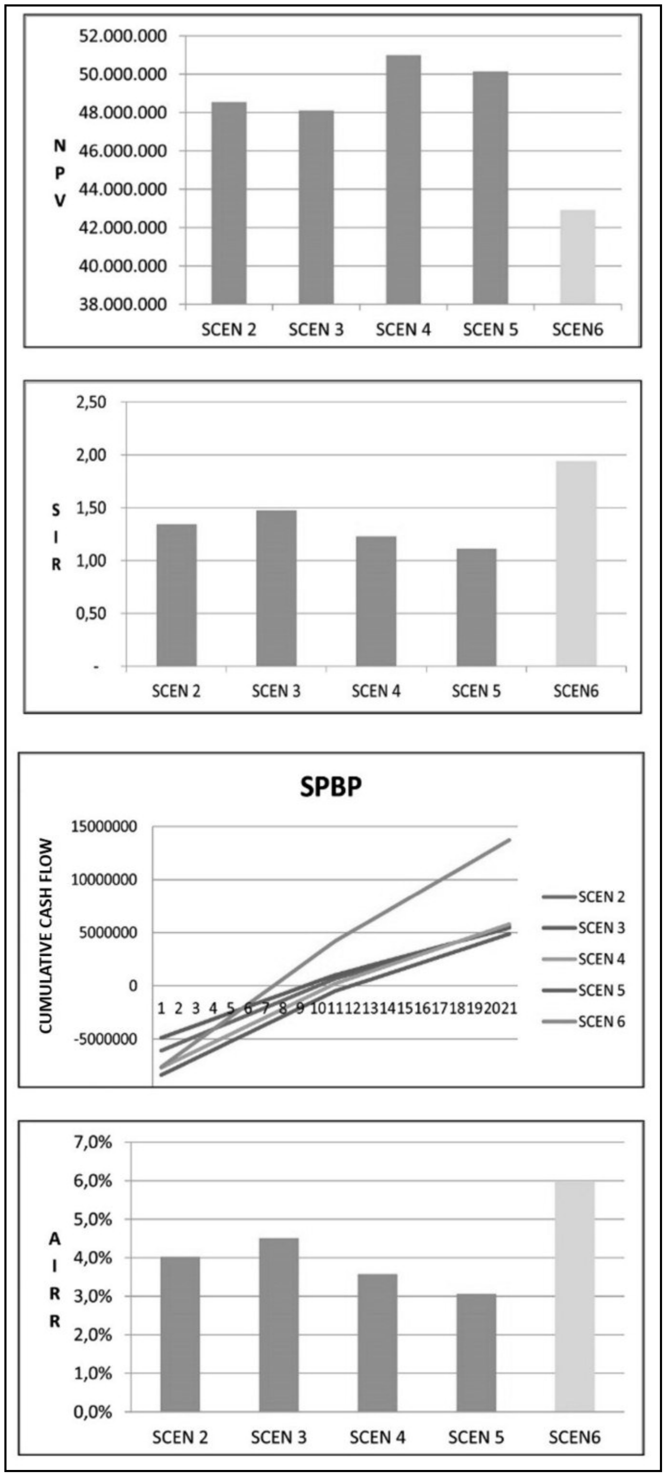

Figure 3 - *Ecomonic performance indicators: graphical representation*

5.3 Energy analysis and economic analysis: comments on the results

To conclude the analysis, we should compare the performances of the different scenarios, identifying the most convenient measures from both an energy and an economic viewpoint, considering also the margins of uncertainty due to the forecasting character of the evaluation.

As hinted at earlier, from a joint reading of the results Scenario 6 proves to be the most convenient one, making full use of tax deductions (which the district heating network does not avail itself of) and, at the same time, using in the most efficient manner only the renewable energy source thanks to the coupling with high-efficiency heat pumps. It is nonetheless true, however, that the useful surface needed to meet requirements is excessively significant and scarcely available within a large/medium-density urban area. Just as we should consider that recourse merely to photovoltaic energy, if not associated with storage systems of the energy produced, would imply either an over-production in some periods of the year and the day (if the system was designed to ensure the daily requirement in the winter season as well) or the need for energy during the cold season, if designed solely in accordance with the expected annual requirement.

It is moreover interesting to note how the implemented project, Scenario 3, proves to be the most appealable after the "borderline" case (Scenario 6); in line, that is, with the international literature that sees in the integrated exploitation of energy sources the best energy procurement system, especially on a district scale. The recourse to solar technologies and to the local district heating network, powered by the cogeneration station, represents the most convenient scenario in an economic sense as well.

If we then analyse the results by comparing the performances of the different, specific technological components used in the different scenarios (by for instance comparing plant characteristics with envelope performances), we can observe various "preferability rankings". Without dwelling on the merits of the individual results obtained by the application, it is interesting to note, as a general behaviour, that not always an intervention capable of producing optimal performances from an energy viewpoint proves to be the preferable one in terms of global cost containment as well. More generally, the results of the energy analysis and the economic analysis applied to alternative options often prove not to be interrelated.

This complexity data is the target, moreover, of recent studies inclined to testing operational methods for the production of joint energy-environmental and economic analyses that assume, as basic principle, the need to reason in terms of global perfomance (Thiebat, 2013; Fregonara *et al*., 2013).

The remarks hitherto put forward are supported, lastly, by the deterministic Sensitivity Analysis, applied beginning with the preliminary identification of the critical variables. More specifically, account is taken of the costs for replacing doors and windows, for the supply and installation of the insulation, for the cogenerator, for the photovoltaic plant, for the solar heating plant, and lastly for the energy costs.

The results of the sensitivity analysis, graphically expressed in Figure 4, highlight the fact that a variation, albeit minimal, of the insulation package cost is capable of significantly affecting the indicators, even without subverting the final result.

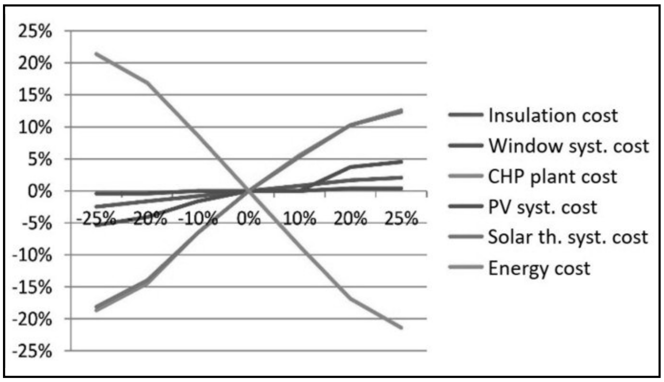

Figure 4 - *Sensitivity Analysis*

The steepest curves in the spider graph represent, let us remember, the variables that can affect the results the most.

In conclusion, it is still useful to stress, from a purely economic viewpoint, that following the interventions prefigured by the different scenarios positive impacts are expected in terms of exploitation, on the whole district scale, of the assets therein included. Impacts traceable on the one hand to the redevelopment of the entire territorial sub-segment, and on the other hand to the Energy Class shift that concerns the products. Even this confirms the growing sensibility of the real estate market towards the energy perfomance characteristics of the properties, with returns on the sectoral research. The energy perfomance of the building complexes is a quality element that is translating into value, eventually affecting the conduct of both public and private subjects involved in the market choices and in the decision-making processes (Morano *et al*., 2017; Bottero *et al*., 2017).

6. CONCLUSIONS

The work illustrated was the opportunity to try out the LCCA approach on a real context, referred to a circumscribed territorial scale and yet entailing a significant shift compared to the dimension more usually dealt with – the building -, with impacts in terms of research and experimentation. It has represented, moreover, the opportunity to test application of the LCCA approach to a case already targeted by a previous retrofit intervention: a "post retrofit intervention" viewed within a differently mature technological and market context.

It has furthermore enabled comparison between a project developed on an urban district scale, based on the principle that the more convenient approach is the integration between local energy production technologies (district heating by gas cogeneration, photovoltaic, solar heating energy), and a project capable of maximising recourse to a solar energy generation technology, at the same time easy to manage and control (especially for the scenario where photovoltaic energy alone is resorted to).

Aside from the results of the methodological application, the study has aimed to stimulate reflection over the potential offered by switching from the single building scale to the territorial sub-segment one in the simultaneous presence of several energy sources, with all the implications and complexities, at the level of systems and at an evaluative level, which is entailed thereby. Complexity that might lead, however, to important openings for territorial governance and the definition of policies compatible with the energy containment objectives and with the required performance requirements, while being simultaneously, sustainable from an economic and financial viewpoint.

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