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Appraisal of thermal premium in green building practice at urban scale. Methodological preview

Attributions. Antonino BARBALACE coordinated the research works of PAU GIS University Laboratory components, and authored paragraphs: 5, 6, 8. Domenico Enrico MASSIMO conceived and set up the research and authored paragraphs: 1, 2, 3, 4, 9. Cinzia FRAGOMENI performed scenario analysis and energy quantification at building and urban level. All economic valuations, cost appraisal, financial assessment, energy quantification, GIS applications of the research are Copyright©1999-2011MassimoDomenicoEnrico.

1. Background

States and international organizations are aware of Earth environmental emergency, as well as of urban ecological and energy crisis. One causal factor among several is the dis-investment of existing old settlements and the migration of a high percentage of rural population to metropolis. A dramatic consequence is the wild urbanization of all available rural agricultural land surrounding original built areas in large cities and the increase of urban congestion which causes, among others effects, artificial mobility, private cars over-use, energy over-consumption, air over-pollution.

Communities and territories are addressed by leading organizations to treasure and re-use the consolidated old settlements, not to abandon them, and therefore to save the open and arable land surrounding cities and metropolis, by means of: revitalization of economy in historic towns and old villages; physical rehabilitation following their economic revamping. For more dense settlements already existing "Green Urban Conservation" actions are introduced and addressed such as: restoration and retrofitting interventions, characterized by both bio-ecological and cultural sustainability over the wide heritage; energy rehabilitation of buildings for dramatic consumption reduction; adoption of renewable energy sources; diffusion of zero mile decentralized energy production (with no transport) aiming to make local communities energy independent and, as much as possible, self-sufficient.

2. General objective of the research

General objective of the research is to design and assess the potential relationship between urban rehabilitation strategies and construction energy efficiency within a Green Building framework and to introduce and valuate Sustainable Conservation at urban level, by setting-up strategies alternative to present inefficient *status quo* in city energy management. Innovative Green Urban Conservation practices at large scale supported Green Building approach imply a larger initial cost, which can be defined as "first cost negative premium", with respect to common practices.

Research aims to set-up a general methodological and appraisal framework that might be employed in different contexts to quantify energy saving and financial pay-back period of green investment.

Research deals with the principle of New Sustainable Urbanism, specifically faces and confronts the emergency of the growing energy consumption in human settlements, particularly in urban areas. It investigates the possible global solution to the inefficient thermal behavior of modern buildings as well as to the excessive civil energy consumption, caused in particular by the growing use of devastating summer air-conditioning units in hot climate countries. It has been built-up a connection between urban rehabilitation strategies and building energy efficiency by integrating several information and valuation elements within a GIS framework: 3D city modeling; design of actions for a Green City; cost estimate of actions for Green City investments; valuation of running energy yearly demanded; comparison with the *status quo* as well as further un-sustainable scenario; appraisal of operating costs in alternative scenarios; comparative ecological impact analysis of alternative scenarios; comparative economic analysis over time of alternative scenarios.

The program is divided into steps going from the climatic-energy behavior enhancement of single buildings to the generalization of the interventions at urban and city scale.

Impacts of Green Building urban global actions should be:

1. *insulation* of cities for structural and forever energy saving i.e. thermal "passivation" of existing buildings and hydro, humidity and moisture regulation (perspiration) of constructions;
2. consequent sizeable *reduction of urban energy consumption* for both winter heating and (more important) devastating summer air-conditioning in the existing buildings;

   integrated with:
3. *energy production* (decentralized at zero mile) by means of solar photovoltaic and thermal panels at urban block level integrated into building pitched and flat roofs;
4. *latest scientific innovations* of sun engined chiller systems or (more complex) solar cooling that finally makes possible to produce the today high costly summer air-conditioning from the sun;
5. *reduction of CO_2 emissions* in consequence of lower and lower fossil material combusted;
6. *curb of total running cost* in the building life cycle defined "thermal positive premium" to be assessed over-time in:
   - environmental terms (by summing up all the avoided pollutants);
   - energy terms (by summing-up the avoided kWh or NegaWatt, *i.e.* not employed);

- monetary terms by summing-up all savings including the new interesting monetization (even too low) by European Union that equalizes the damage to 30 Euros per each ton of CO_2 emitted;
- financial terms, actualizing future money, using appropriate rates.

To test the methodology, research has developed a Case Study, concerning Calabria, a Mediterranean region located in South Italy, and its largest town Reggio Calabria (180.353 residents at 2001 Census) by simulating a "green quarter" or "sustainable neighborhood", *i.e.* an "urban energy district" in a city section called Latin Quarter of: 6.400 residents; 490.000 m^2 of total quarter gross area; 125 urban blocks; 840 buildings; 2.500.000 m^3 of constructions; 800.000 m^2 of apartments.

3. Applied research. First output preview

Anticipating the first outputs of the research, regarding the entire neighborhood, they show a reasonable and interesting time of pay-back of the "initial cost negative monetary premium" of the investment finalized to perpetual energy saving by ecological insulation and bio-passivation of buildings. The "initial cost negative monetary premium" is largely due to the higher costs of sustainable conservation and to the related better quality of techniques and bio-ecological materials employed in sustainable *chantiers*, if compared with the mediocre level materials commonly used in ordinary refurbishment yards. This larger and higher initial intervention costs are set-back, off-set and counter-balanced by a dramatic reduction of the yearly energy management costs. Saving is achieved thanks to the rehabilitation interventions able to produce high energy efficiency.

Second output show also a potential grand total energy saving of around 33 millions of kWh per year in the entire neighborhood, considered in Case Study, thanks to sustainable urban conservation interventions.

In addition, thermal passivation can be integrated with the newest technologies for decentralized energy production from renewable sources such as the solar panels (photovoltaic usable also for sun chiller system and solar cooling) for both winter heating and summer air-conditioning, producing a significant independency from fossil resources import and energy commodity international market.

4. Alternative scenarios of intervention: sustainable *versus* un-sustainable

As introduced above, research highlights the possibility to act and intervene for conservation and maintenance on the same kind of decay with alternative approaches (comparative scenarios technique).

Present state scenario

Status quo, do-nothing.

Sustainable scenario

It is conservative and high energy efficient. Its design adopts ecological techniques and materials to reduce heat dispersion toward the outdoor as well as to cut fossil fuels consumption for heating and conditioning and consequently to lower down related CO_2 emissions. In the case of sustainable scenario materials are: plaster renovation of external wall coating for insulation makes use of "volcalite", *i.e.* mortar made of natural hydraulic lime (clinker-cement free) with special inert elements highly insulating, such as expanded perlite, vermiculite and pumice; roof sealing and waterproofing renovation adopts natural perspiring membranes with aerating, ventilating and insulating groove panels made of natural materials such as fluted cork (©lis); transparent surfaces with single glass are replaced with double ones with air space; aluminium windows are replaced by new ones made of highly insulating materials. The physical characteristics of natural hydraulic lime "volcalite", adopted and used in the designed sustainable scenario, do not allow the passage of heat through masonry and reinforced concrete and consequently dispersing thermal bridges are always reduced, often significantly mitigated and sometime neutralized. During cold winter time, this kind of building material keeps the masonry average temperature high as well as that of the internal walls, insulating and in so doing fostering energy saving and a better indoor climatic quality. Cork then, thanks to its physical characteristics has a high elasticity, it is an excellent thermal and acoustic insulator, it has a high resistance to wear, fire, rats and insects, and it is also perspiring and steam permeable. A special form with groove in the upper part of the panel makes it possible to lower down the roof floor temperature during the hot sub-Saharan summer of low Mediterranean cities, by allowing air circulation.

Un-sustainable scenario ("built just to code")

Its design employs popular materials commonly used in ordinary construction yards, *i.e. chantiers*, characterized by poor thermal behavior and mediocre (almost inexistent) insulating characteristics that sometimes make worse and worse the energy dispersion compared to the *status quo ante*. These materials are on one side cheaper to buy and easier to install, but on the other side they do not help neither building efficiency nor city energy management because the do not have good thermal and insulating characteristics. To this list belong: mortars made only of sand and cement with a high level of transmittance, applied to vertical surfaces; epossidic membrane without neither insulating nor perspiring characteristics, in substitution to the old natural asphalt for roofs and balconies waterproofing; single glasses; highly emissive, not-ecological and inefficient metals (aluminum) for doors and windows.

5. Proposed valuation methodology

A system framework has been set-up for valuation of Green Urban Conservation Strategy, tested in the Case Study and articulated in some main activities such as:

- "Geodatabase" activity *i.e.* application of Geodatabase to reality, and design of a geographic information system dedicated to get urban information;

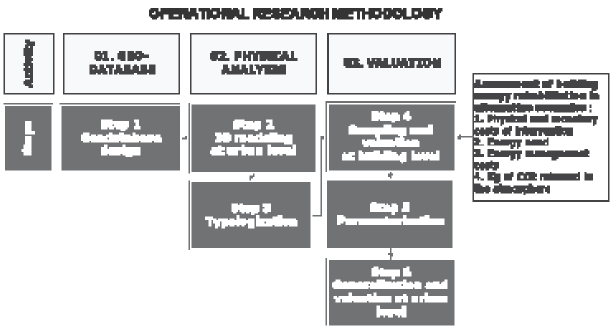
- "Physical Analysis" activity *i.e.* geometrical modeling at city scale and urban 3D information system: 3D; typologization;
- "Valuation" activity *i.e.* behavioral modeling and integrated energy-ecological-economic-financial analysis: sampling; parameterization; generalization.

Each activity produces outputs which intersection allows to achieve one of the research goals, *i.e.* to calculate the energy saving, the rehabilitation costs as well as the energy management costs at single building level. After that it is possible to generalize the results at the uncommon and unprecedented valuation level of neighborhood and entire urban areas.

Urban strategy aims to redirect the unavoidable ordinary maintenance works toward building passivation with specific interventions involving external plaster and roof renovation with natural ventilation and insulation in an original way that allow the works to be done only in the exterior avoiding the resident to move leaving their houses.

The above summarized implementation process of strategy integrated valuation is therefore articulated in the steps of the following operational methodology drew-up in the Flow Chart.

Flowchart. Proposed valuation methodology.



The progressive levels of detail of the steps are described below.

ACTIVITY 01. GEODATABASE

Step 1. "Geodatabase design"

It consists in the design of the tailored and dedicated information system and creation of feature classes, tables, fields, relationship classes, raster datasets, subtypes, topologies, domains.

The Geodatabase is the fundamental structure where all the various kind of data (raster; vector; alphanumeric; others) coming from the different steps in which the research has been divided, will be stored, organized, processed and managed as vital essential information to perform integrated valuations.

ACTIVITY 02. PHYSICAL ANALYSIS

Step 2. "3D modeling at urban level"

It is sub-divided in two sub-steps: terrain 3D model; building 3D model.

Sub-Step 2.1. "Terrain 3D Model"

Focus is the representation of the Case Study area within a Geographic Information System (GIS) in order to calculate the exact extension of the territory of potential intervention and mostly to generate a realistic terrain 3D model. Then, data collection is performed to get precious cartographic maps in raster and vector format, crucial to create the 3D model of the Case Study area. These pieces of information are georeferenced, and the Triangular Irregular Network (TIN) of the Study Area *i.e.* the 3D terrain model is created. It represents the basis for all the following quantitative and valuation analyses.

Sub-Step 2.2. "Building 3D Model"

It makes it possible, with growing details and according to the characteristics of each specific step, to know in quantitative terms for the entire city area: built area; m^3 of buildings; m^2 of external wall coating for insulation; m^2 of flat/pitched roofs; other pieces of information such as m^2 of built unit surface (*i.e.* apartments). These data are finalized to the analytic assessment of rehabilitation costs and energy need of the buildings and the generalization at city scale.

Step 3. "Typologization"

"Typologization" divides the built environment in typologies on the basis of architectural characteristics. Given the purpose to apply the operational methodology at city level, four prevailing building typologies have been detected within the Case Study Area: Historicist/Neoclassical; Liberty; Rationalist; speculative; others.

ACTIVITY 03. VALUATION

Step 4. "Sampling and valuation at building level"

"Sampling and valuation at building level" selects representative buildings of each typology within the Case Study Area. At first, for each prototype building included in sample, it performs:

- more accurate and detailed geometric survey on the field;
- documentation with data archive mining;
- more detailed decays and cracks analysis;
- census and list of needed interventions.

Afterwards, for each alternative scenario (present state *i.e. status quo*; sustainable; un-sustainable) the following analyses are designed, simulated and valuated:

- appraisal of the physical and monetary costs of intervention of rehabilitation by means of Elemental Factor Analysis (Price Analysis), in alternative scenarios;

- assessment of the energy need and efficiency (kWh), before and after the intervention, in alternative scenarios;
- valuation of the energy management costs, in alternative scenarios;
- quantification of CO_2 released in the atmosphere, in alternative scenarios;
- financial assessment overtime, for each alternative scenario.

Cost appraisal of intervention on each building (represented by AutoCad®, GoogleSketchUp®, ArcGIS®, PAUGis software®) is particularly accurate and it is based on the Elemental Factor Analysis (Price Analysis) i.e. a detailed cost appraisal technique.

Calculation and estimate of the energy need of buildings is highly accurate and detailed, and performed by adopting and comparing different approaches (and related software) of physical-technical calculus (Termo4®; Docet®; Best-Class®).

Energy needs are assessed and expressed in kWh per m^2 per year, both: for the present state, derived from direct analyses; and for of the rehabilitated buildings after the intervention. The comparison makes it possible to obtain the potential differential *i.e.* the energy saving. It is expressed in terms of total kWh so called Negawatt. Negawatt are converted both: in Euros for family budgets; and last but not least kilograms of CO_2 avoided and not released into the atmosphere, thanks to the climatic rehabilitation.

All the above valuations are performed for real world buildings designing and simulating interventions. Then they are converted in unit data, related to m^2 of buildings, thanks to "parameterization" step.

Step 5. "Parameterization"

"Parameterization" allows to derive parametric data of bio-architectural rehabilitation costs and energy need, starting from the sample buildings chosen and analyzed as prototypes.

Therefore, the "parameterization", when already derived, is used as a feedback tool to perform quick *ex-ante* appraisal and to know the size of both rehabilitation costs and energy need of the buildings in different scenarios: present state; sustainable; un-sustainable.

Thanks to the results achieved during the "Sampling" step, it is possible to calculate quickly per each sample building: cost per m^2 of front renovation and roof insulation in each typology and for each scenario; energy need expressed as kWh per m^2 in each typology and for each scenario before and after works.

These parametric data included in the Geodatabase allow to estimate for each building: intervention costs of the energy rehabilitation; energy need in each scenario; the energy saving per year; period of financial pay-back of the higher monetary "first cost premium" due to the sustainable intervention of energy passivation of buildings; the avoided kilograms of CO2 released in the atmosphere.

Step 6. "Generalization and valuation at urban level"

"Generalization and valuation at urban level" calculates the total size of the interventions and assesses their impacts in different scenarios at the uncommon valuation scale of city level. Single parametric data of intervention cost (€) and energy saving (kWh) are multiplied by the quantitative physical data. Then, the assessment at block, neighborhood, and at urban and city level is achieved.

It allows to know at city and quarter level the size of: total costs for thermal passivation of buildings; energy saving; ecological effects in terms of CO_2.

Results are summed up providing the costs for both the physical intervention and the energy management of the specific building typology and therefore for the entire neighborhood.

The system allows to estimate at neighborhood level: intervention costs of the energy rehabilitation; quantify at neighborhood level the energy need in each scenario; energy saving per year; period of financial pay-back of the higher monetary premium due to the sustainable intervention of energy passivation of buildings; avoided kilograms of CO_2 released in the atmosphere.

6. Real world "sustainable neighborhood" design and appraisal. Case study

New wider eco-urban approach as well as new technological strategic support (such as GIS tools) have been deployed and employed in a real world design and social experimentation, constituting the Case Study, concerning the fostering-up of an "Ecological Urban District" in an already existing urban area.

Case Study is localized in the cited town of Reggio Calabria (Italy), in the Northern part of its Liberty reconstruction re-built after the earthquake and subsequent dramatic tsunami of 1908.

At present time this area or neighborhood is largely inhabited by university students of four University Schools (Architecture; Engineering; Agriculture; Law) and it has been named "Latin Quarter" *i.e.* "neighborhood surrounding University location". It has been chosen as area of Case Study finalized to design a potential "sustainable neighborhood". The neighborhood has been usefully mapped into GIS giving the impressive and sensible extension of: 490.000 m^2 of Quarter total area; 125 urban blocks; 840 buildings distributed covering a built-up area of 208.000 m^2 with 2.500.000 m^3 of built area; 800.000 m^2 of apartments; over 400.000 m^2 of fronts to be insulated; about 180.000 m^2 of roofs to be aerated-ventilated and insulated; a population of 6.400 residents, plus thousands of University Students living there as non-resident renting rooms and flats privately and unofficially during the academic year.

Urban Sustainability interventions for the real world Case Study (especially insulation with natural materials) have been designed and valuated in their environmental and energy impacts. Natural insulation and ventilation reduce dramatically the needs and energy consumption for winter heating as well as for more demanding summer air conditioning. Impressive is also the amount of avoided kg and costs of CO_2.

Moisture reduction enhances the quality of life even if it is on frontier of appraisal science.

The approach might be applied to different contexts in many cities in the world.

7. Building prototype: example from real world

The real world plan at neighborhood scale has been implemented starting from experimentation on a prototype building through a real world construction yard, doing a real "passivation" work.

The reconstruction of Reggio Calabria after the earthquake of 1908 is characterized by high and great urban qualities, among which the most important is represented by its urban pattern, based upon Urban Block structure, with streets and avenues converging into public squares. Each Urban Block includes one or more buildings.

Main and peculiar characteristic of Reggio Calabria is the small dimension of its Urban Blocks (about 50x50 meters), and therefore the average footprint of a medium block is around 2.500 m^2. Among the positive effects of this exemplar pattern there is a rich articulation of urban spaces and a consequent high street density and variety.

After over seventy years, the most prominent guru and reviews of Architecture, Urban Studies and Planning, re-discovered the quality of the above pattern and this framework is now one pillar *de facto* of the New Urbanism international movement.

The building prototype of Case Study is the Urban Block #128 named Palazzo De Mojà after its designer. It includes four main buildings and is located inside the Latin Quarter on the continuation of Corso Garibaldi (the Liberty elegant commercial main street of Reggio Calabria). It was built between 1935 and 1939, and stylistically belongs to the Italian Rationalist Architectures. Today this building is the prestigious seat of the Regional Court of Administrative Law Judges.

A Sustainable Global Maintenance Program for the Urban Block #128 according to the principles of New Urbanism has been designed. It consisted in: ecological insulation and aeration of the pitched roof by adopting lis natural cork (©lis); *restitutio ad integrum* of interiors according to the original identity (loyalty to the original drawings and materials) and spatiality of the project; adoption of bio-ecological materials, such as "volcalite" for example, to improve the healthiness of the building.

The core of the intervention has been the energy rehabilitation of the New Court Room, covered with 15 elegant trusses made of local conifer wood that with its 20x12 meter was the area of higher dispersion of both winter heating and summer air-conditioning. Therefore, it has been designed and done a sustainable intervention of energy rehabilitation by introducing in the roof covering, beside and over the natural perspiring membrane, an insulating and ventilating material *i.e.* the natural cork.

Impact of Sustainable Conservation is a huge energy saving, and the yearly annual energy consumption (*i.e.* the Primary Energy Need) is reduced by over 50% only with this intervention: from 91,14 kWh/m^2 to only 42,50 kWh/m^2, just for winter heating. Not considering the great saving over the more expensive summer air-conditioning. The first positive effect is the well-being of users as well as a considerable reduction of the energy management costs. Now the building is monitored with temperature data loggers to control the real effect of insulation and natural ventilation upon internal temperature and constantly compared the external temperature and to the correspondent internal one of a benchmark common building built just to code.

8. The urban level simulation and assessment. First results

Strategy implementation aims to redirect and change the ordinary maintenance works toward building passivation with specific interventions consisting in external plaster and roof renovation including winter insulation as well as summer natural ventilation and sun engined chiller.

By operating a generalization of building prototype in the Case Study area, it is at first considered the passivation of vertical surfaces of 400 buildings (50% of existing), with thermal-insulating plaster made of mortar composed by natural hydraulic lime and inert and optimal insulators such as expanded vermiculite, perlite and pumice. It can be foreseen a cycle of only six or eight years for the completion of a program of 400.000 m^2, 1.000 m^2 per building with an average of 82 m of perimeter and 12 m of height. By considering the thermal-insulation and ventilation of roofs it is estimated a work of 180.000 m^2.

The hypothesis of front passivation for 400.000 m^2, for a maximum cost of €/m^2 80 determines a "first cost" *i.e.* a potential minimum investment of € 50.000 per building and of € 32.000.000 for the entire neighborhood. By hypothesizing the insulation and ventilation of roofs for 180.000 m^2 with aerating natural cork for a "first cost" of €/m^2 60 it is possible to quantify the total investment of € 10.800.000.

It follows that the total cost of passivation for the 50% neighborhood is € 42.800.000.

It is of paramount importance to keep in mind that a larger part of this amount must be spent in any case for mandatory unavoidable maintenance works. Then sustainability accounts only for a small part of expenses, exactly the differential for bio-ecological materials.

These expenses are shortly recovered by the owners of single housing with annual installments constituted by the substantial saving on energy bill, before described and quantified.

The existing total built volumes, assessed by means of the built geographic information system, are 2.500.000 m^3. By considering an average height per unit of 3 m, it is possible to give a first estimate of the built unit surface in the entire neighborhood of about 830.000 m^2 to be managed on energy side quantifying the so-called Potential Energy Need (FEP).

Sample analyses performed on the different building typologies have shown with reference to the present state an average theoretical energy need per m^2 during one year of 100 kWh/m^2. By multiplying this parametric data for the total m^2

of all buildings it can be obtained a first rough result of the total potential energy need for the entire neighborhood of about 83.000.000 of kWh per year. Considering an average cost of energy of 0,15 €/kWh it can be obtained a total expenses of energy management of about € 12.450.000 per year.

Research, field work, yard observations, as well as specific experimentations performed on the sample prototypal buildings, assuming an intervention of sustainable energy rehabilitation, have highlighted an average reduction of, at least, 40% of the theoretical amount of energy need. Considering the average cost of 0,15 €/kWh it can be obtained a smaller total expense per year for energy management of about € 7.500.000

The energy need of the sustainable scenario is likely to be reduced to, at most, 50.000.000 kWh every year i.e. 50.000 MWh. The total physical differential is therefore equal to 33.000.000 kWh (i.e. 33.000 MWh) not consumed (Nega-watt) and the consequent monetary amount of year energy saving is of € 4.950.000 (33.000.000 kWh x 0,15 €/kWh).

Considering a total saving of passivation equal to € 4.950.000 per year, the correspondent payback can be assessed in about 10-11 years, at steady rate of 4% (Table 1).

Last but not least, the production of a MWh of energy by burning oil releases into the atmosphere about 255 kg/MWh of CO_2. An intervention at neighborhood level, besides a monetary saving of € 5.000.000 per year, with 33.000.000 kWh less every year, produces an ecological benefit of CO_2 yearly not released in the atmosphere equal to 8.415.000 Kg (8.415 ton) of CO_2 per year. The economic values of this "avoided damage" can be compared to the cost of international Carbon Capture Storage (CSS) of the same CO_2 amount summed-up to realize saving, expressed by the "avoided energy expenses". Considering a value €/ton 100 for avoided pollution, additional saving in terms of CO_2 is equal to € 841.500 per year subtracted from yearly cost of energy in sustainable scenario, that change from € 7.500.000 to € 6.658.500, shortening furtherly the period of return around 9-10 years. To this preliminary valuation it will be added the extraordinary saving achievable by the summer air-conditioning, which quantification results will be edited in the next-near future.

9. Conclusions

The experimented research strategy allows to set-up a large scale plan to enforce Urban Sustainability policy and to achieve the objectives and goals of energy saving programs.

The operational methodology allows to: precisely quantify and estimate the general urban plan for energy saving; reduce the necessary times of investigations; provide guidelines to firms, investors, realtors, households, Society and to local Governments on the possible results achievable by large urban scale interventions; derive keystone prototype data.

In fact, in the specific research here presented the clustering of buildings per

Table 1. Energy rehabilitation of the entire Latin Quarter. Energy consumption in two alternative scenarios and economic pay-back of the passivation costs (assessed 42.800.000 €) in 10-11 years. i=4%.

	Yearly Cost of Energy Consumption		Rate i=4%	Actualized Value of Energy Consumption		Balance	
(1) Years	(2) Status Quo	(3) Sustain Scenario	(4) Actualiz Coeff	(5) Status Quo	(6) Sustain Scenario	(7) Saving	(8) Saving Sub-total
	€ x1000	€ x1000	(1+i)-n	€ x1.000	€ x1.000	€ x1.000 (7)=(5)-(6)	€ x1.000
1	12.450	7.500	0,9615	11.970	7.211	4.759	4.759
2	12.450	7.500	0,9245	11.510	6.933	4.576	9.335
3	12.450	7.500	0,8889	11.066	6.666	4.400	13.735
4	12.450	7.500	0,8518	10.604	6.388	4.216	17.952
5	12.450	7.500	0,8219	10.232	6.164	4.068	22.020
6	12.450	7.500	0,7903	9.839	5.927	3.911	25.932
7	12.450	7.500	0,7599	9.460	5.699	3.761	29.694
8	12.450	7.500	0,7306	9.095	5.479	3.616	33.310
9	12.450	7.500	0,7025	8.746	5.268	3.477	36.787
10	12.450	7.500	0,6755	8.409	5.066	3.343	40.131
11	12.450	7.500	0,6495	8.086	4.871	3.215	43.346
12	12.450	7.500	0,6245	7.775	4.683	3.091	46.437
13	12.450	7.500	0,6005	7.476	4.503	2.972	49.410
14	12.450	7.500	0,5774	7.188	4.330	2.858	52.268
15	12.450	7.500	0,5552	6.912	4.164	2.748	55.016
16	12.450	7.500	0,5339	6.647	4.004	2.642	57.659
17	12.450	7.500	0,5133	6.390	3.849	2.540	60.200
18	12.450	7.500	0,4936	6.145	3.702	2.443	62.643
19	12.450	7.500	0,4716	5.871	3.537	2.334	64.978
20	12.450	7.500	0,4563	5.680	3.422	2.258	67.236
Tot.				169.110	101.874	67.236	

typologies has allowed, by surveying and studying carefully a limited number of paradigmatic prototype and sample buildings, to obtain reliable results in a reasonable time, to employ less activity, to reduce the costs for the analyses, estimate, assessment and design.

At the end, besides the most relevant outcomes above cited, research has achieved the possibility to: sort out parametric costs and energy consumption data per m^2; develop subsequent cross-analysis thanks to the build-up of a Geodatabase within a geographic information system; deepen the assessment for entire urban areas; include environmental and monetary effects of avoided CO_2 pollution, and considering them in assessment of "first cost" period of return.

All the created data, collected information, performed analyses, are crystallized safely in a stable, querying, flexible and open Geodatabase system.

Finally, intervention simulation in the Case Study area shows that with the building passivation strategy it is possible to achieve an energy saving of 33 million of kWh in the neighborhood each year, by analyzing just winter heating, taking into mind and account that impact on expensive and demanding summer air-conditioning will produce even more and more benefits both monetary and ecological.

The methodology has been tested in a real world yard prototype. The post-yard permanent monitoring of temperature and humidity, performed with remote data loggers has positively confirmed the *ex-ante* valuations.

The positive results achieved give two empirical positive evidences:

- physical, in terms of energy saving thanks to sustainable bio-ecological materials employed;
- economic, with a short period of pay-back of the "initial cost monetary negative premium".

These empirical evidences encourage to follow the path of Sustainable Urban Conservation at large scale and to test the methodology in other prototype buildings and in different climate zones.

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Figures

Figure 1. Case Study, Reggio Calabria, Italy. Geometrical modeling of urban spaces. Urban scale 3D city model. "First 3D modeling at urban level". The Latin Quarter.

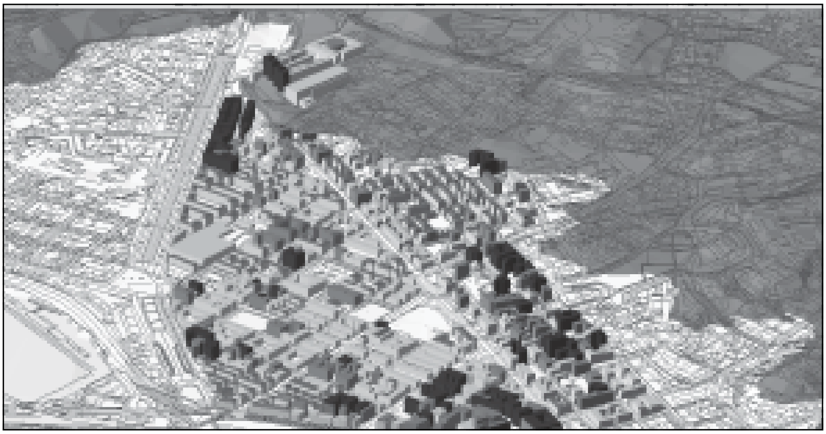

Figure 2. Case Study, Reggio Calabria, Italy. Geometrical modeling of urban spaces. Building scale 3D city model. "Photo-realistic 3D modeling of buildings from field survey". The building prototype: Urban Block #128.

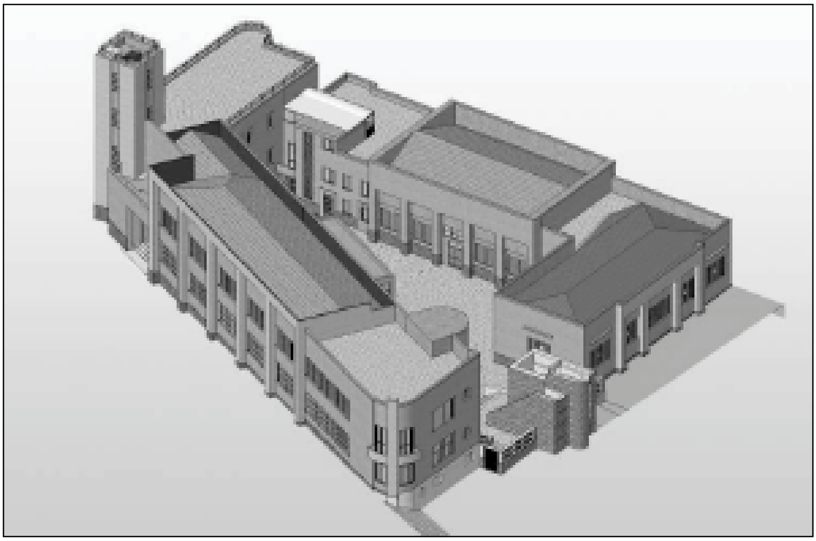

Figure 3-4. Case Study, Reggio Calabria, Italy. Urban Block #128. *Chantier* or sustainable retrofitting yard for real world implementation of Green Conservation with adoption of bio-ecological cork in buildings prototype.

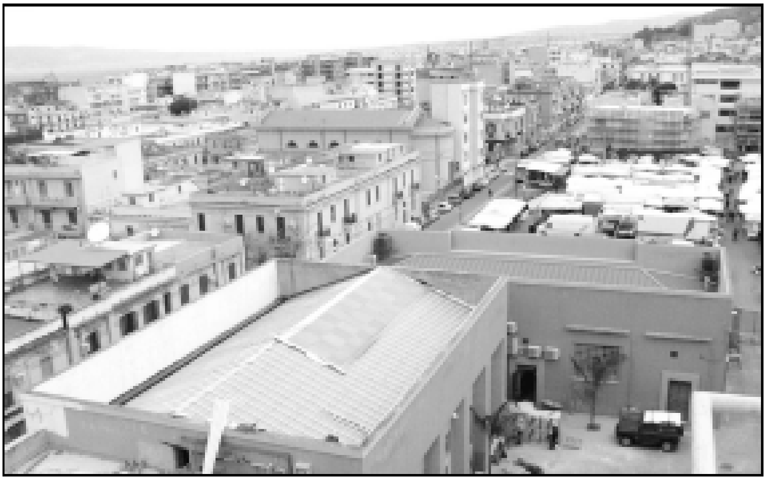

Figure 5-6. Case Study, Reggio Calabria, Italy. Buildings prototype: Urban Block #128. From top: interior design; immediate re-use of refurbished sustainable Court Room.