GREEN DISTRICT. CASE STUDY IN REGGIO CALABRIA

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Abstract

This research deals with energy consumption in urban and construction management and CO_2 emissions. By setting up a specific methodology and experimenting it on unprecedented District and City scales, the research is able to compare energy consumption and CO_2 reduction in different intervention scenarios, one of which is based on the main pillars of Green Conservation and Ecological Retrofitting.

A Valuation Framework, helped by WebGis tools, supports the present research while integrating:
- unprecedentedly detailed 3D city-modelling;
- alternative scenarios (Sustainable *versus* Business as Usual) for building and city energy management;
- cost estimate of maintenance investments in alternative urban scenarios;
- valuation of energy management in alternative scenarios;
- overtime economic and financial analysis, comparing alternative scenarios.
- two Case Studies where real world design have been performed in Reggio Calabria (Italy) and Boston (Usa); the first one is going to be implemented in the real world as an experimental <Sustainable Urban District Retrofitting> project in an urban neighbourhood whose features include:
  - 6,400 residents, plus thousands of University Students living there (Latin Quarter) as non-residents in rented accommodation during the academic year;
  - 490,000 m^2 of district total area;
  - 125 urban blocks;
  - 840 buildings covering a built-up area of 208.000 m^2;
  - 830,000 m^2 of apartments;
  - 2,500,000 m^3 of constructions.

“Ecological passivation” (i.e. insulation works and materials used for the non-consumption of energy) is the key outcome of the real world experiment. A global appraisal of such an experiment provides an evaluation of the economic and ecological aspects quantifying the initial slightly higher costs of passivation (“negative cost premium for Sustainability”) and assessing the number of years needed to pay-back the additional cost of investment which is offset by a large saving in constant energy spending. It has been demonstrated, both theoretically and practically, that it is possible to reduce energy consumption and by up to 40%, and to pay back the initial slightly higher costs of passivation in just five years.

1.Introduction

The construction sector at large and, in particular, the energy management of existing buildings, according to international assessments, is responsible for over 40% of the total energy consumed on Earth. They are, among others, the major causes of the waste of resources, the demand for fossil fuels and resources, CO_2 emissions and the planet’s pollution levels.

Pollutant emissions, caused by combustion and one of the final stages in the settlement process, are among the major causes of Global Warming (GW) according to the Intergovernmental Panel on Climate Change, IPCC (2007, 2013, 2014). Analysts and policymakers, worldwide, are showing an increasingly growing interest in the energy and environmental performance of the construction industry. The improvement in the energy performance of both newly built and existing buildings is a physical and economic challenge for the future of urbanization. Research into the causes of the ever increasing and widespread environmental decay and the consequent desire to draw up common strategies to overcome the problems have been stimulated by the pending ecological and environmental disaster which threatens the planet’s very existence .

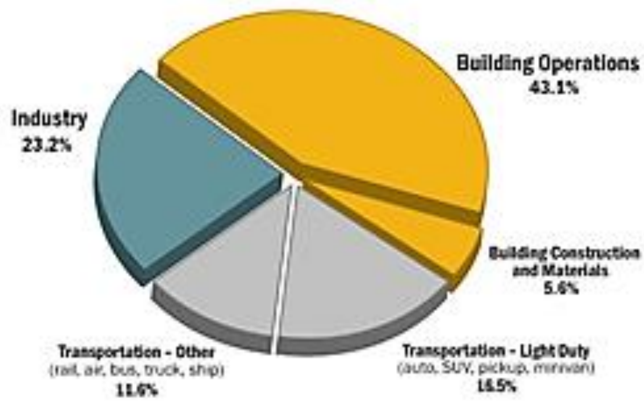

Figure 1 U. S. Energy consumption by sector. Source ©2011-2030 Inc. \ Architecture 2030. Data Source: U. S. Energy Information Administration (2011).

Sustainable cities are those cities that are more attentive to citizens' needs, cities in which energy - and environmental issues and socio-economic interests are integrated harmoniously (co-evolution). They anticipate the role of the private sector and focus on the economic growth of the local market (Caragliu, Del Bo, Nijkamp, 2011). In the last few years several methods and tools have been developed to evaluate both how energy and environmental building impact even at city levels. A WebGis based tool developed by MIT (http://www.urbmet.org/)l, and the NYC energy usage map created by Sustainable Engineering Lab (formerly Modi Research Group) at Columbia University are examples of such instruments and provide reliable information concerning the annual building energy consumption at block and lot level. Estimation is calculated by using a mathematical model based on statistics, and not on individual building data.

However, while the tools to evaluate building energy - environmental efficiency have increased, a fact which is also due to the issue of European standards on energy consumption reduction, the sustainability evaluation carried out using an analytics model has been less investigated (Massimo, Musolino, 2013).

Research tries to overcome the lack of a shared and common methodology which would allow an objective assessment of sustainability at an urban level and the impact that ecological investment would have on energy saving and mitigating pollution levels.

2.Methodology

This research aims to set-up, on an urban scale, a general methodology and appraisal framework to quantify energy saving and the financial pay-back period of several green investments. A case study approach is adopted in this research in order to verify how effective this methodology is and if it can be applied in different contexts. This research, which deals with the principle of New Sustainable Urbanism, faces and confronts the emergency of the ever growing energy consumption levels in human settlements, particularly in urban areas. It investigates the possible global permanent perpetual solution to the inefficient thermal behaviour of modern buildings as well as to excessive civil energy consumption, and the consequent CO_2 emissions, which are one of the principal causes of the Global Warming.

A connection between urban regeneration - rehabilitation strategies and building energy efficiency has been developed by integrating several information - gathering and evaluation elements within a WebGis framework. These elements include: 3D city modelling; the drawing-up of plans for a Green City, the cost estimate of Green City investments, the evaluation of the yearly energy needs, a comparison with the *status quo* as well as further un-sustainable scenarios, an appraisal of operating costs in alternative scenarios, a comparative ecological impact analysis of alternative scenarios, and a comparative economic analysis over time of alternative scenarios concerning payback period of "negative cost premium for Sustainability" .

The research is divided into steps which range from the climatic-energy behaviour enhancement of single buildings to the generalization of the interventions at an urban, district and city scale.

The impacts of Green Building global interventions at an urban level should be:

1. **insulation** at an urban level for structural and permanent energy saving, *i.e*. thermal "passivation" of existing buildings and hydro, humidity and moisture regulation of constructions;

2. a consequent sizeable **reduction** in energy consumption at an urban level needed for both winter heating and (more importantly) devastatingly expensive summer air-conditioning in the existing buildings;

3. **energy production** (decentralized at zero mile) placing solar photovoltaic and thermal panels on the pitched and flat roofs of buildings ; this work is to be carried out on an urban block level;

4. **reduction** of CO_2 emissions at urban level as a consequence of the increasingly lower quantity of fossil material being burnt;

5. a **curbing** of total running costs in the building life cycle (defined as “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 Megawatt, i.e. not employed); - monetary terms (by summing-up all savings) ; - financial terms, envisaging future financial gains, using appropriate rates.

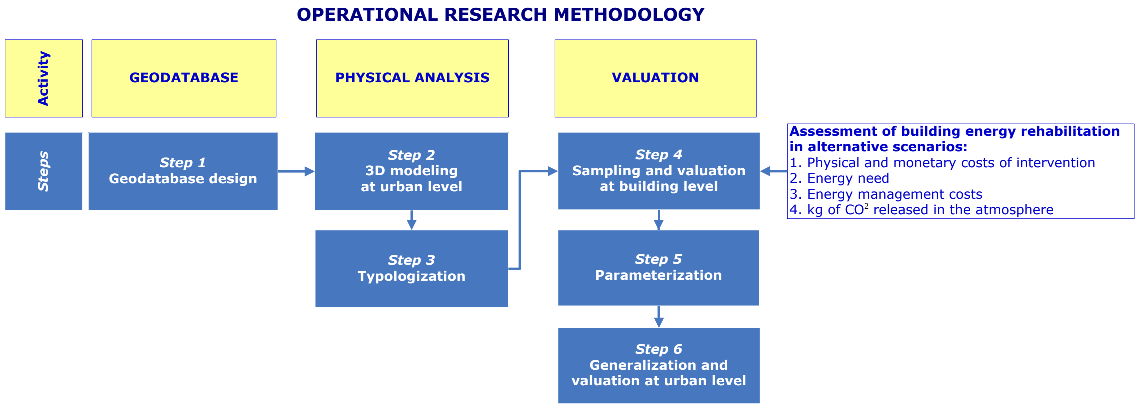

Figure 2 Logical Chart. Methodology for sustainable retrofit generalization at district and urban level

A system framework has been set-up to evaluate the Green Urban Conservation Strategy tested in the Case Study and divided into some principal steps such as:

- “Geodatabase” activity i.e. the application of Geodatabase to reality, and the design of a geographic information system designed to obtain urban information;

- “Physical Analysis” activity i.e. geometrical modelling at city scale and the use of an urban 3D information system: 3D; typologization;

- “evaluation” activity *i.e.* behavioural and metabolism modelling together with an integrated energy-ecological – economic - financial analysis: sampling; parameterization; generalization.

The overlapping of the results derived from the different activities allows one of this research goals to be achieved, *i.e.* to calculate the energy saving, the “passivation” or rehabilitation costs as well as the energy management costs at a single prototype building level. As a result, the effects on a neighbourhood and an entire urban area (unusual levels of evaluation) can be generalized.

Urban strategy aims to redirect the unavoidable everyday maintenance works towards building passivation employing specific interventions involving external plastering and roof renovation using natural ventilation and insulation. Work is only carried out on the exterior without any inconvenience to the resident. The above summarized implementation process of strategy integrated evaluation is therefore articulated in the steps of the following operational methodology drawn up in the Flow Chart. Methodology implementation at an urban level, allows for the identification of areas of potential or actual decay to which priority of intervention should be given.

3.Case Study at district level. Alternative intervention scenarios

In order to test the methodology, research has developed a Case Study where the “passivation” of a whole neighborhood has been designed, implementing the methodology in a real world situation.
The Case Study, the so-called Green District or Latin Quarter, is located in Calabria, a Mediterranean region in Southern Italy, in the town of Reggio Calabria, which was rebuilt at the beginning of 1900 as an interesting Liberty – *Art Noveau* new settlement. Reggio Calabria is a first class Urban City with an exemplary road network, urban block pattern, wonderful squares, public buildings, private constructions, and an extraordinary waterfront. Nowadays this urban settlement is referred to as such by the International Movement: Congress of New Urbanism (CNU).
This research highlights the possibility to work for urban conservation, energy consumption and CO_2 emission reduction using alternative approaches (comparative scenarios technique).

A.Sustainable Scenario

This scenario is conservative and highly energy efficient. It uses, at a building level, ecological techniques and natural materials in order to reduce outdoor heat dispersion as well as to cut fossil fuels consumption for heating and air-conditioning. These factors, consequently, lead to lower CO_2 emissions. The steps to be taken for a sustainable scenario are as follows:

1. **Plaster renovation** of external wall coating for insulation making use of "volcalite" (© hd system), *i.e*. mortar made of natural hydraulic lime (clinker - cement free) with special highly insulating inert elements, such as expanded perlite, vermiculite and pumice.

2. **Roof insulation** and **waterproofing** renovation employing natural perspiring membranes with aerating, ventilating and insulating groove panels made of natural materials such as fluted cork (© lis).

3. **Windows replacement**: single glazing is replaced by double glazing; aluminium windows are replaced by new ones made of highly insulating materials.

B. Business as Usual (BAU) scenario

This scenario employs popular materials commonly used in ordinary construction yards or building sites, *i.e*. *chantiers*. These materials are characterized by poor thermal behaviour and mediocre (almost inexistent) insulating characteristics which sometimes worsen the energy dispersion compared to the *status quo ante*. These materials are, on the one hand cheaper to buy and easier to install, but on the other hand they help neither building efficiency nor city energy management because they do not possess good thermal and insulating characteristics.

1.**Plaster renovation,** in the BAU scenario, is carried out using mortars made only of sand and cement with a high level of transmittance, applied to vertical surfaces;

2. **Roof insulation** using epoxy resin membrane which possesses neither insulating nor perspiring characteristics, in substitution to the old natural asphalt for roof and balcony waterproofing;

3. **Window replacement** using highly emissive, non-ecological and inefficient metals (aluminium) for doors and windows.

Figure 3 Case Study. Reggio Calabria, Italy. The Latin Quarter. Identification of the Case Study area. Source: author's workingout from a Bing Maps view. Top right: University and PAU Department.

4.Prototype Building. Example from the real world

The methodology is based on a real world experiment carried out on prototype buildings in a "passivation building site" or yard or *chantier*.

An example of this is the "passivation" work performed on the large Main Room of the Regional Administrative Judicial Court of Reggio Calabria, using "green" window, wall, roof insulation and ventilation.

Based on the envelope thermal analysis carried out previously, a Global Maintenance Program for Urban Block #128 has been designed. It consisted of the ecological insulation and ventilation of the pitched and flat roofs by adopting natural Italian cork; plaster renovation using natural hydraulic lime and window replacement.

Thermal analysis highlighted the fact that the wooden roof of the wide hall, which covers 20 x 12 meters (240

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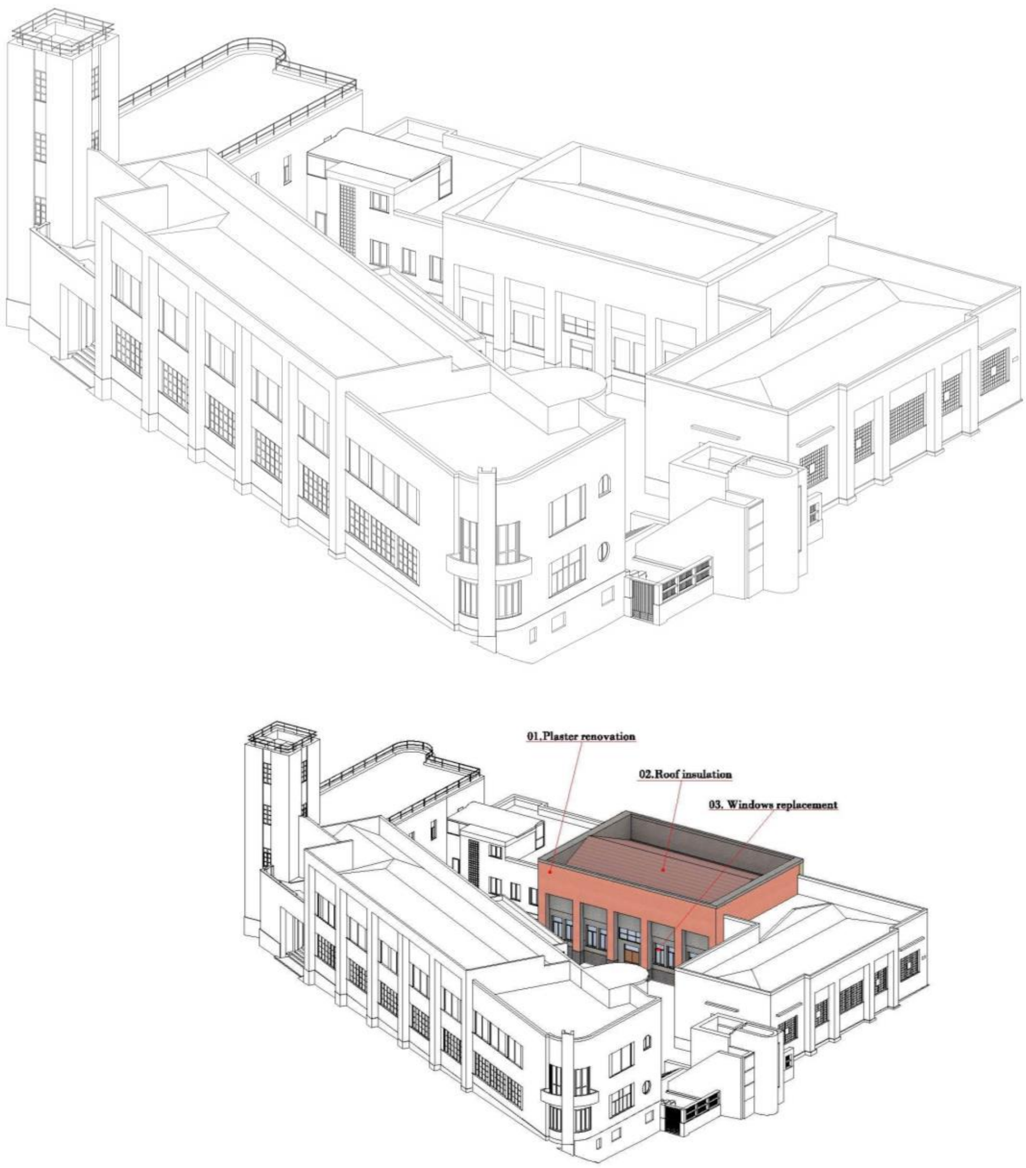

Figure 4 Case Study. Reggio Calabria. Italy. Prototype building. Court Room roof "green" insulation

Huge energy saving resulted from this intervention and the annual energy consumption was reduced by almost 50%. The first positive effect is a considerable reduction in energy management costs. By adopting an analysis period of 20 years, with a discount rate of 4% for the "business as usual" scenario and "sustainable" scenario, there is a 8-10 year payback period. Further innovation is the post-intervention monitoring through the use of temperature sensors (i-buttons). Today, the building is constantly monitored by temperature data loggers to control the effect of insulation and ventilation upon internal temperature, which is constantly being compared to the external temperature. The data duly processed demonstrated the success of the intervention in terms of indoor comfort (temperature - moisture) achieved, allowing its generalization at district, urban, city scales.

5.Real world Green District implementation. Design and appraisal

A new broader eco-urban approach as well as a new technological strategic support system (such as valuation WebGis tools) have been employed in a real world design and social experiment. These form the basis of the Case Study (Massimo, 2015), which is concerned with the development of an "Ecological Green Urban District" in an already existing urban area. The neighbourhood or district or quarter has been usefully mapped into a 3D valuation GIS giving the following significant information:

- 490,000 m^2 of total district area;
- 125 urban blocks;
- 840 buildings covering a built-up area of 208.000 m^2 with 2.500.000 m^3 of built volume;
- 830,000 m^2 of apartments;

- over 400,000 m^2 of fronts in need of insulating;
- 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 (Latin Quarter) as non-residents in rented accommodation during the academic year.

Urban Sustainability interventions aimed at passivation in the real world Case Study which involve above all insulation using natural materials have been designed and evaluated taking into account their environmental and energy impacts. In prototype experimental buildings, natural insulation and ventilation reduce the energy consumption for winter heating as well as for more demanding summer air conditioning. The reduced quantity of CO_2 produced is significant.

"The classification of building types" divides the built environment into typologies on the basis of architectural characteristics (considering both the structural and architectural language). On the basis of the detailed analysis conducted and thanks to the in-situ testing and feedback, a specific thematic map has been created which identifies the four different prevailing building typologies within the Case Study area: an eclectic form of architecture present in Reggio Calabria; Liberty; Rationalist; Contemporary \ speculative. For each typology, intervention, energy, and saving cost parameters have been derived from similar experimental prototype buildings. The use of WebGis tools make automatic assessment at neighbourhood or district level possible. By using the cost and energy parameters calculated, it was possible to estimate the following information for the entire district:

- the total physical amount of interventions in the two alternative scenarios (usual maintenance or BAU *versus* innovative ecological "passivation");
- the total monetary investment cost of interventions for each scenario and typology;
- the energy consumption for each scenario and typology;
- the total annual running costs in each scenario and typology;
- the pay-back period needed for the additional cost of "passivation" (sustainability premium);
- Kg of CO_2 emitted into the environment for each scenario and typology.

6.Latin Quarter **Green District. New evidence**

Strategy implementation aims to redirect the everyday maintenance work towards building envelope passivation with specific interventions, which involve: external plastering , roof renovation and window replacement. A generalization methodology has been performed from the architectural prototype level to the district – neighbourhood – quarter level in the Case Study area, providing the following first assessment .

1. Total monetary intervention costs

Front passivation. The passivation of vertical surfaces (front; elevation) of 400 buildings (50% of the total) is considered. 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 in perimeter and 12 m in height can be envisaged. Front passivation for 400.000 m^2 at average cost of 80 € \ m^2 determines a potential minimum investment of € 32.000.000 for 50% of the total neighbourhood (400.000 m^2 x 80 € \ m^2 = € 32.000.000).

Roof insulation. The thermal - insulation and ventilation of roofs for 180. 000 m^2 using aerating natural cork has a cost of 60 € \ m^2. The total investment amounts to € 10.800.000 for the whole neighbourhood (180.000 m^2 x 60 € \ m^2 = € 10.800.000).

Summing-up. It follows that the total cost of passivation for 50% neighbourhood is € 42.800.000 (*i.e*. for the whole 100% district: € 85,600,000 in the sustainable scenario *versus* € 64,400,000 in the BAU scenario).

It is of paramount importance to keep in mind that most of this sum must be spent, in any case, on mandatory, unavoidable maintenance work carried out in an unsustainable traditional way. At this point sustainability accounts only for a small part of the expense, that is the difference in price between traditional and bio-ecological materials. This additional expense is quickly recuperated by the single-house owner because of the annual saving on energy bills, as described and quantified above.

2. Energy consumption

The existing total built volumes, assessed by means of the newly created GIS are 2,500,000 m^3. By considering 3m as the average height per unit, it is possible to give a first estimate of the built unit surface in the entire neighbourhood at about 830,000 m^2 to be subjected to energy management. Sample analyses performed on the different prototype buildings have shown an average theoretical energy need per m^2 a year of 100 kWh\$m^2$ in the BAU scenario and of 60 kWh\$m^2$ in the alternative sustainable scenario. By multiplying this parametric data by the total 830,000 m^2 of all buildings, a first rough estimate of the total energy need for the entire neighbourhood of about 83,000,000 kWh per year for the BAU scenario *vs* 50,000,000 kWh per year for the sustainable scenario can be calculated. Therefore, in the sustainable scenario there is a concrete saving of 33,000,000 kWh per year.

3. Total annual running costs

If the average crude cost of energy production is 0.19 €\kW, then, in the BAU scenario, the cost of energy management comes to about € 12,450,000 per year. Research, field work, construction site observations as well as specific experiments performed on the sample prototype buildings (assuming an intervention of sustainable energy rehabilitation) have highlighted an average reduction of 40% in the theoretical amount of energy needed. Considering the average cost of 0,19 €/kWh, a lower total expenditure for annual energy management could be about € 7,500,000 Consequently, the money saved on energy consumption per year is € 4,950,000. Considering that a total saving in passivation is equal to € 4,950,000 per year, the correspondent payback, at a steady rate of 4%, can be assessed in about 5 years.

7.Results

All the results are summarized in the tables below. The energy saving and pollution mitigation are up to 40% . The payback period for Passivation Strategy at district level can be assessed in about 5 years .

Table 1 Green District. Data Summary. Built area and volume

Blocks	n	125
Buildings	n	840
Roof area	m^2	180.000
Facades \ elevation	m^2	400.000
Volume	m^3	2.500.000

Table 2 Green District. Data Summary. Passivation investment and energy

		BAU	**Sustainable**	D	D
		x 1000	x 1000	x 1000	%
Investment work costs	€	64.400	85.600	+21.200	+24
Energy needs. Year	kWh	83.000	50.000	-33.000	-40
Management costs. Year	€	12.450	7.500	-4.950	-40
CO_2 emission. Year	kg	16.000	9.500	-6.500	-40

Table 3 Green District. Fast Pay Back Period in five years (i=4%)

Years	**Energy Saving**	**Rate**	**Saving Actualiz**	**Saving Sub-total**
n	*€ x1000*	*(1+i)-n* i=4%	*€ x1000*	*€ x1000*
1	4.950	0,961	4.759	4.759
2	4.950	0,924	4.576	9.335
3	4.950	0,888	4.400	13.735
4	4.950	0,851	4.216	17.952
5	**4.950**	**0,821**	**4.068**	**22.020**
6	4.950	0,790	3.911	25.932
7	4.950	0,759	3.761	29.694
8	4.950	0,730	3.616	33.310
9	4.950	0,702	3.477	36.787
10	4.950	0,675	3.343	40.131
…..	…..	…..	…..	….
20	4.950	0,456	2.258	**67.236**
Total			**67.236**	

8.Conclusions

This research has set up and tested an experimental approach - strategy - – methodology based upon a Case Study of urban regeneration. Particular attention was paid to the environmental and climatic dimensions on the built environment. This experimented research strategy allows the researcher to set up a large scale plan to en-force an urban Sustainability policy and to achieve the objectives of energy saving programs. The operational methodology allows the researcher:

- to meticulously quantify and estimate the general urban plan for energy saving; to reduce the necessary times of investigations;
- to provide guidelines to firms, investors, realtors, households, Society and to local Governments of the possible results that can achieved through large urban scale interventions;
- to derive keystone prototype data.

In fact, in the specific research here presented, the grouping of buildings according to typology has allowed the researcher (by surveying and studying carefully a limited number of paradigmatic prototypes and sample buildings) to obtain reliable results in a reasonable length of time with relatively little effort. This has helped to reduce the costs of analyses, estimates, assessment and design.

Finally, apart from the most relevant outcomes cited above, this research has succeeded in sorting out the parametric costs and energy consumption data per m^2. It has also developed a subsequent cross-analysis thanks to the creation of a Geodatabase within a WebGis. It has finely tuned the quality of assessment for entire urban areas and included the environmental and monetary effects of avoided CO_2 pollution, while considering them in assessment of “initial cost” period of return. All the created data, collected information and performed analyses are organized in a stable, querying, flexible and open Geodatabase system.

In conclusion, intervention simulation in the Case Study area shows that with the building passivation strategy 33 million of kWh can be saved in the neighbourhood each year. This figure incorporates solely the energy saved on winter heating but does not include the vastly higher costs (monetary and ecological) involved in summer air-conditioning. The methodology has been tested in a real world construction site prototype. The post-construction site permanent monitoring of temperature and humidity, performed by remote data loggers, has positively confirmed the ex-ante valuations. The positive results achieved give two empirical positive results:

- 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 results encourage us all to follow the path of Sustainable Urban Retrofitting on a large scale and to test the methodology in other prototype buildings and districts, and in different climate zones.

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