Existing Buildings' Energy Upgrade: An Economical and Environmentally Sustainable Opportunity

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1 Introduction

Building energy conservation has become a crucial issue both for environmental and economical perspectives of the global problem. In despite of all the International pressure for improving buildings' energy performance, the global economic-financial crisis is delaying this process, given also several market barriers. At the same time the building sector represent the 36 % (Green Building Council 2011a) of total global energy consumption, and there is a huge opportunity for both companies and buildings' owners to obtain environmental benefits with profitable investments.

In these years a huge research effort has been focused on energy performance optimization through several interesting methods for assessing building energy efficiency (Pisello et al. 2012a) also involving a complex multi-building approach for reducing the energy requirement of specific urban contexts (Pisello et al. 2012b; Xu et al. 2012).

Given the slow buildings' renovation rhythm, also exasperated by the actual global crisis, the upgrade interventions are assuming an increasingly important role in the built environment scenario. For this reason the purpose of this contribution is to answer several questions about building energy performance improvement, involving both engineering and economics issues. At the beginning of this chapter we will explain what specifically the retrofitting procedures are, which could be the main engineering interventions on buildings, and which could be the typical market barriers against the implementation of the process.

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The start-point of this contribution is the research related to buildings' energy retrofitting procedures in terms of engineering practice (Ge et al. 2009) and in terms of operations management through continuous commissioning practice (Liu et al. 1997; Pisello et al. 2012c). This specific procedure is often able to achieve important energy conservation amounts with low-cost interventions on existing buildings.

Considering also the necessity to apply an effective integrated process, this contribution provides an interesting interpretation while coupling technical and economical perspectives of the complex issue. The case study assessment translates this approach into operative practice guidelines, giving us the possibility to relate the engineering interventions to the benefits in terms of energy requirement reduction and indoor comfort optimization, and finally to the economical-financial effort.

2 What Is Building's Energy Retrofit

The energy efficient retrofit is a complex of procedures that involves multiple disciplines. It is aimed at improving buildings' energy efficiency, indoor comfort conditions, and also at reducing the building life-cycle environmental impact.

The retrofit subject starts with an energy assessment but it necessary involves an exhaustive investigation of both the economic and the environmental side of the complex issue. In fact the improvement of buildings' energy efficiency is not the only purpose of the retrofit, because the cost-effectiveness and the environmental variables are the protagonists of this issue as well.

The retrofit path begins with the building energy audit to figure out where, when, why and in which way energy is used following efficient or inefficient procedures. A careful energy audit is the most performing tool for outlining the building energy performance with respect to all the equipment. The beginning purpose is indeed to draw the scenario Zero, that is the scenario before the retrofit. Walking through the energy audit allows to the progressively understanding of these main features:

- The equipment energy consumptions trends and costs,
- The indoor thermal behavior and the relative indoor comfort conditions in different locations within the space,
- The occupants' satisfaction level with respect to each specific building use: retail/commercial, industrial, office space, residential, etc.
- The operation and maintenance strategies already implemented within the building controls.

With all these elements we are able to discover the power consumption of every individual equipment, its energy efficiency, and its capability to achieve indoor comfort conditions with respect to the cost level corresponding to the baseline (scenario Zero).

Applying this procedure for example to the lighting system, we can evaluate the system energy consumption for the scenario Zero, indoor comfort failures, possible improvement in reducing consumption achievable with new efficient technologies, relative costs and benefits, etc. In this way we can mark out several strategies that could be implemented considering different project goals. For example we can define profitable procedures to achieve different budget levels, comparing the results with the specific project budget constraint; or different comfort levels. Building retrofit purpose could also involve several innovative procedures if we need to implement specific innovative technologies, that could make us able to obtain specific acknowledgments and credits.

In every retrofit activity the project goal clear definition is the first step of the integrated design process. Building energy retrofit is indeed a complex procedure that needs deep and fertile integration of different competences, to achieve the project goal in terms of energy efficiency, environmental impact and cost effectiveness.

2.1 Buildings Environment and Benefits of the Energy Upgrade

The purpose of this analysis is to outline an explicative and objective panorama of the building energy improvement, trying to make order within the vortex of information coming from different market and energy sources.

What it is already acknowledged is that improving energy efficiency through a successful strategy is important for several reasons. It allows to reduce utility bills of energy and water, to optimize indoor comfort level, to extend the life of all the equipment, and to finally reduce the environmental impact due to the facilities management improvement.

Within this complex scenario the main difficulty is the quantification of the financial and environmental benefits that these green strategies provide. In fact there is often no objective comparison with the conventional buildings' construction practice and financial mechanism. Thus this is the main reason why it is still difficult to quantify these interventions in a coherent way with respect to traditional types of investments. Also the common benefits, such as energy savings, should be looked at through a life cycle cost assessment, not just assumed in terms of upfront costs. In fact it is obvious that from a life cycle savings standpoint, each saving source coming from investment in sustainable retrofit dramatically exceed any additional upfront costs (Kats et al. 2003).

Thus the questions we should answer now are not just based on the specific activity cost effectiveness, even if in the following paragraphs we will deal with this issue as well. But the strategic questions to answer should concern all the sources of benefits that energy retrofit is able to carry out for companies, not just limiting the issue to a common source of investment, and the relative cash flow.

Building energy upgrade has to be seen by companies as an intelligent path to save money of course, but at the same time, to improve brand public image and affiliates productivity concerning the environmental satisfaction, lowering absenteeism and healthcare costs, refreshing employee attention and affection to the purpose. The retrofit path will lead to the competitive differentiation, the sustainability and brand equity improvement, with relatively modest cost.

All these remarks arise from a buildings' environment picture of reality all over the world that points out the oncoming upgrade demand on existing buildings estate. According to facts, all over the world buildings account for more than one third of the global greenhouse gasses (Green Building Council 2011b). Despite the International policies constraints the projections over the next 25 years forecast a growing of CO_2 emissions from buildings that is faster than those from any other sector. In particular commercial building will increase this, growing velocity of 1.8 % a year through 2030 (U.S. Green Building Council press release 2007). Focusing on urban environment, buildings are responsible for more than 50 % of greenhouse gas emissions in most cities and for more than 70 % in largest cities such as New York and London (William J. Clinton Foundation 2011). Thus, given the necessity to reduce the environmental stress operating on buildings sustainability optimization, it is actually trivial to understand that a methodical action on existing buildings is actually necessary, given that buildings yearly new construction is close to 1 %.

2.2 Market Growing Attention and Obstacles Along the Way

Analyzing the most recent information collected by the Energy Efficiency Indicator global survey in 2011 (Institute for Building Efficiency 2011), there is an undeniable increasing attention paid on controlling energy consumptions and optimizing building energy efficiency (Fig. 1 [Institute for Building Efficiency 2011]). Only the 3 % of the participants to the survey, that have the complete market and energy responsibility of their buildings, declares to have not forecasted any energy reduction for 2012, while the 58 % expects to reduce energy consumption following internal or public purpose of energy retrofitting.

Despite the proven energy and economical opportunity to optimize energy efficiency of existing buildings, a huge amount of potential is still contributing to the "energy efficiency gap", especially for those companies and households where energy efficiency does not represent the highest financial concern compared to other sources of cost.

With respect to the data concerning the energy use in buildings (industrial, institutional, commercial, and residential sector), it is possible to outline typical barriers to buildings energy uograde. These are:

– Huge settlement effort: a successful building energy upgrade is still perceived like a insurmountable amount of time consuming operations for analyzing different strategies, that are not often managed by the same person, company or authority.

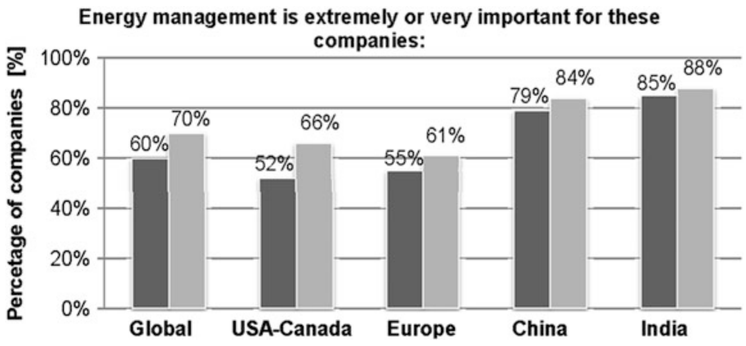

Fig. 1 Companies that identify energy management as extremely or very important

- Public barriers: they are actually due to the instability of public energy policies, that are often more focused on energy supply issue than energy efficiency improvement (GreenMax Capital 2009).
- Lack of information and awareness about opportunities: many occupants of residential buildings or small companies are not conscious about the effective results of retrofit, both from an energy and environmental field, and also from an economical point of view. Furthermore, for example in households sector, energy performance is still related to social and private occupants' attitude. Many studies demonstrate the huge effect of human and social attitudes in reducing building energy use (Xu et al. 2011) and that the average time needed to implement new technologies within the attitudes is about 4 years (de T'Serclaes 2007).
- Chaos in the energy price perception: the common perception about energy price is often unclear and governed by time-variable public subsides that for sure help the market running, but at the same time, they contribute to create a sort of fog perception about effective costs. This element also aggravates the first barriers just described.
- Lack of technical expertise: the reference people usually addicted to energy retrofitting, especially for single houses or small interventions, are still often focused just on one specific ring of the energy chain. Thus it is often necessary to consult different people from different organizations to achieve a complex and successful building energy retrofit, with the relative analysis of the intervention cost-effectiveness. This tortuous path makes the retrofitting less accessible and attractive for both households and companies.
- Energy saving randomness: the saving prediction is deeply related to the effective building operations, occupants' behavior and equipment maintenance process following the retrofit. This element contributes to give the impression that achievable benefits and related investment payback is not really quantifiable. At the same time ex post energy monitoring and continuous commissioning is reasonably applicable just in large retrofitting interventions. Thus this barrier impacts especially small buildings' owners.

– Indirect link between investment and consequent benefit: in the retrofitting process often the decision maker, or the building owner, is responsible for the retrofitting investment, but he is often not the direct beneficiary of the energy saving benefits. That is the reason why this kind of market has to be assessed considering several kinds of benefits, not just maintaining the traditional cost-benefit criteria. At the same time the decision maker can take advantage from other sources that are difficult to quantify, like higher rents, public incentives, brand image.

The analysis of upgrade constraints make frankly understand the multipurpose issue, for all the reasons just mentioned. There are indeed so many externalities that cannot be assessed through a single judgment criteria. Analyzing the energy retrofitting drivers (Institute for Building Efficiency 2011) all over the world, even if there is an increasing attention to the energy management, the main purpose is the financial benefit, and the main barrier is related to the investment cost. The list below represents the global 2011 classification of the drivers of efficiency with respect to the companies' perception about the energy efficiency interventions' implementation:

1. Energy cost saving
2. Government incentives and rebates on utilities prices
3. Brand public image green improvement
4. Increasing energy security
5. Greenhouse gas reduction
6. Existing facilitation policies.

In this phase of the analysis it is important to deepen the barriers specifically related to the financial effort of the energy improvement investment. First of all the initial cost of the investment is often a barrier difficult to overcome, especially during International economic crisis periods like this. The risk associated to the investment is often made huger by the difficulty to monitor the real benefit after retrofitting. These same benefits are the result of many factors involving both technical improvements (energy equipment and controls efficiency) and human features (increasing awareness and social constraint). Also the discount rate, being related to the investment risk level, could be seen as a random variable for the reasons just explained. And for the same reasons the traditional opinion views the energy efficiency investments more risky than reality, when they are naturally able to reduce the dependence to the randomness of the fuel price.

Another fundamental element is the payback time. During last years experience the building retrofitting investments were perceived as long-term investments just for the lack of ability in assessing and monitoring the following benefits. This misunderstanding is also demonstrated by the building's lifetime that is naturally longer than 30 years, and that naturally makes this kind of intervention particularly appropriate. In the case study section of this chapter we indeed will deal with one of the several successful retrofit investments, where the beginning assumption was to reach a payback time shorter than the lease period at all.

3 Main Building Energy Upgrade Initiatives

The purpose of this section is not to give a technical explanation of possible retrofitting strategies, because there is already a very exhaustive literature concerning different strategies. On the contrary in this phase we want to introduce the whole-building approach specifically aimed at analyzing, comparing, and optimizing the effectiveness of each action.

The main focus of the whole-building upgrade approach is not to look at individual technologies, trying to maximize the effect of each technology independently. By this time real experience is able to demonstrate that the best result in terms of energy saving could be reached by the optimization of the single strategies, integrated within a whole complex initiative that could involve both stand-alone buildings but also network of buildings. Typical energy savings amount arise up to 30–50 % given by a whole-building energy improvement, while focusing on just one technology, the typical saving potential hardly passes the 5 % of whole energy saving.

The most representative example of this approach is the Empire State Building initiative. In this chapter we will specifically analyze a successful global upgrade within this building as case study. The Empire experience have linked several needs about energy optimization, environmental pressure, sustainability issue, cost-effective requirement. Starting from many different input data, the program achieved 38 % of energy saving by implementing a smart system of interventions with a 3-year payback time of the whole investment. The approach consisted of the integration of several measures from the very beginning of the design process. The beginning phase consisted of the assessment of all the possible ideas proposed by several groups, that were more than 60, through periodical charrettes and several presentations organized within integrated review workshops. With the same methodological approach also the building energy audit was completed. Following these previous findings, it was possible to outline a list of potential facility improvement measures aimed at balancing:

- The energy performance optimization
- The carbon footprint reduction
- The maximization of the energy savings
- The positive net present value.

Through the integrated continuous approach, each implemented strategy was chosen and designed considering both single and multiple effects optimization. So for example a renovation of a thermal equipment technology is placed side by side to a passive strategy in order to achieve single benefit related to each technology but also to optimize the mutual effectiveness of multiple interventions. At the Empire this comprehensive approach guided the renovation of the chillers, just after reducing the 30 % of the cooling requirements by windows insulation improvement. Thus the complex intervention at the Empire has concerned eight projects mutually interacting to reach the final 38 % energy saving (Fig. 2).

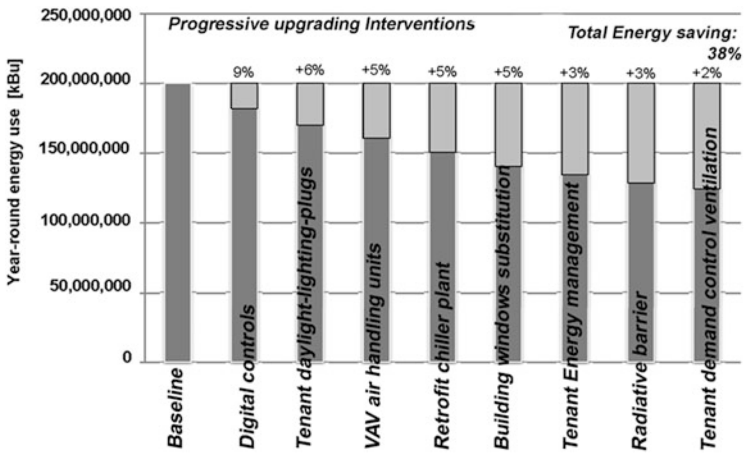

Fig. 2 Reduction of energy requirement within the ESB due to integrated energy retrofits interventions

The Empire Experience created a replicable sustainability model that involves innovative design techniques and O&M (Operation and Management) (Piette et al. 2001) strategies for promoting environmental integrated strategies in existing buildings.

Given the key role of operational efficiency in existing buildings, next section will specifically concern building retro-commissioning/re-tuning as fundamental and relatively inexpensive tool for improving energy efficiency and reducing greenhouse gasses emissions due to buildings life cycle.

3.1 Improving Control and Operations Strategies

In this section we analyze a specific kind of building energy upgrade based just on equipment operations and BEMS (Building Energy Management Systems) techniques (Doukas et al. 2009). The main techniques and the potential benefits of improving building's energy efficiency through operational and control improvements are assessed. This method, also named "building re-tuning (Hatley et al. 2011)", consists of identifying fruitful operations changes that could achieve energy and economical benefits and other possible problems requiring intervention or repair through no-cost or low-cost methods.

Continuously monitoring and solving buildings' operational problems for reducing energy waste are primarily implemented through modifications on the building control system. This kind of actions are mainly no-cost strategies or they could involve few low-cost improvements typically with less than 3 years payback time (Hatley et al. 2011). Building re-tuning includes the identification and the comparison in terms of energy efficiency and cost-effective potential of several

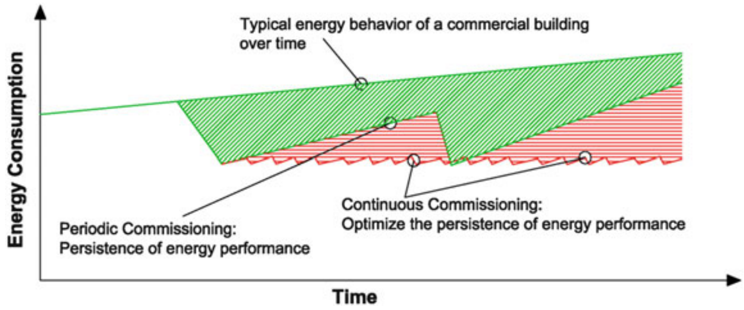

Fig. 3 Building energy typical trend with respect to different commissioning strategies

opportunities for improving energy efficiency. This continuous commissioning program consists of several operations with respect to different building's use and energy plants typologies (Fig. 3 [Hatley et al. 2011]). The main intervention areas are:

– Building's occupants re-scheduling, with respect to the real occupants behavior;
– Temperature and pressure control of the discharge air;
– Heating and cooling control of the Air Handling Units (AHU);
– Management of the fresh air of AHU and economization procedures;
– Intelligent energy zoning, with respect to the monitored thermal zones requirements;
– Actions on the central plant technology and control system.

This kind of intervention on existing buildings could be implemented through a technical sequence consisting of these basic steps:

– Building beginning information;
– Data collection and analysis;
– Identification of operations troubles and outline of resolution procedures;
– Strategies implementations;
– Findings and verification of the improvements;
– Analysis of the impacts in terms of energy and economic benefits.

Collecting preliminary building information means to gather building features that could be useful for the following operative phase. These informations are typically already known by managers and operators. They consists in outlining the overall building design (shape and geometry), defining the main energy equipments of the HVAC system. Another important step consists of the definition of the thermal zones with their equipment features and the typologies of the automation and control system.

The following step consists of investigating potential operational issues that require time history analyses and optimization improvements. After this, the effective intervention is scheduled through a monitoring plan where all the relevant parameters are collected and trend logs are implemented in the control system.

During the fulcrum of the retuning process operators and control managers are able to analyze the trend-data and begin to implement the first interventions. For making them able to do this, a specific training could be very useful for achieving the best optimization result (Bobker et al. 2011). Starting from the assessment of the building meter profile, many important elements could be registered, such as the energy demand and time of use, occupied/unoccupied periods and other weekend events. They could lead to specific improvement strategies concerning the rescheduling with respect to occupants attitude especially during night hours, weekends, and holidays.

After walking down through the building, it is the time to use the knowledge learned from trend data (PNNL 2011), report all the findings, and choose the design optimization strategies for energy saving. Then it is possible to calculate the year-round energy performance before and after those techniques implementation within the same building. Given the necessity to report and demonstrate the actual energy consumption and savings, it is very important the monitoring process and the building simulation procedures, that are assuming a crucial role within the whole building energy upgrade approach.

Results and findings could also represent the baseline for elaborating and implementing an exhaustive decision support model, hopefully based on the BEMS typical logic (Levermore 2000), able to integrate all the decisive components. To obtain fruitful results, these components typically are (Doukas et al. 2007):

– The sensors' system, that comprehends all the indoor and outdoor sensor for monitoring energy performance and thermal behavior concerning the building environment;
– The controller equipment, that involves all the valves and actuators;
– The decision support unit, that is able to link the sensors results with the intelligent system techniques for selecting and applying appropriate interventions. This is also the specific function aimed at communicating with building's operators through specific interfaces system.
– The building energy database, that collects all the building's data useful for implementing the procedure.

4 Case Study Analysis

Given the main role of the ESB (Empire State Building) as a distinguished prototype for demonstrating the economic and environmental benefits of energy upgrading of buildings, in this section a specific case study within the ESB will be analyzed as "platinum" sustainability intervention.

This case study concerns the office green improvement (Heider and Hartley 2010) of the Swedish construction company Skanska, that occupies the whole 32nd floor of 2,267 m^2 (24,400 ft^2) space. The model project mission was to create a

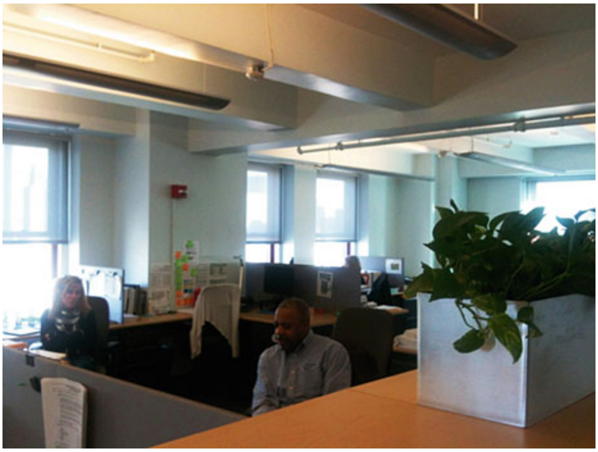

Fig. 4 Natural daylight available at the office workstations of Skanska office

LEED Platinum interior space, with the same budget of a traditional high quality office that could represent a sustainability prototype. The project was also aimed at realizing a comfortable work environment for up to 90 people, with modern and flexible space organization, and the cost-effectiveness of every solution was analyzed within the mission of a less than 5 years ROI value.

4.1 Design Approach for Maximizing Sustainability Benefits of the Retrofit

The design process mission consisted of maximizing the energy efficiency and the occupants' individual controls, the outside natural view and daylight potential (Figs. 4 and 5), tracking all costs and monitoring energy use, with the zero construction waste trough recycling and reusing procedures.

The project consisted in the integration of several architectural and engineering solution and the post-intervention electricity demand was monitored and compared with the previous Skanska high quality office space in Manhattan. After the first year of monitoring Skaska operator were able to register a 57 % of electricity costs with respect to the previous office. So the 15-years saving forecast becomes more than $650,000, considering just the electricity requirements (Tables 1 and 2 [Heider 2011]).

Currently the monitoring system at ESB is able to measure and monitor all the equipment and utilities consumptions. Thus the Skanska new office space could represent a perfect example and baseline reference for future green retrofits. The year-round energy saving associated to the retrofit is more than 185,000 kWh (from about 211 kWh/m^{2}per year to about 91 kWh/m^{2}per year with reference to the ESB

Fig. 5 Outside view of Manhattan from Skanska office at ESB

Table 1 Energy study: utility consumption of the previous Skanska high quality office in Madison Avenue, NY, NY

136 Madison Ave (high quality office)	2008			Total annual, actual	Comparison annual
	JAN actual	FEB actual	MAR actual		
Cost [$]	3,677	3,921	4,209	57,506	85,039
Consumption [kWh]	13,760	15,520	17,920	220,853	326,595
Avg cost per kWh	0.27	0.25	0.23	0.26	0.26
Energy cost/rentable SF	0.22	0.24	0.26	2.36	3,49

office conditioned space). The two main comfort and efficiency improvements were the windows full height scheme and the under-floor air distribution system. The first one guaranteed the daylight to 99 % of occupants with the transparent area by 19 % of the external partitions, achieved by the full exposure windows (6’-4” height).

Following the energy model of the under-floor air system, Skanska engineers predicted 27 % of energy saving for the reduction of the static pressure, with the consequent reduction of the fan energy use, and the increase of the supply air temperature. Large energy saving was also achieved by installing variable-frequency systems, able to control and regulate the airflow with respect to the real indoor requirements.

Table 2 Energy study: utility consumption of the new Skanska office at Empire State Building

Empire State Building, 32nd floor LEED Platinum	2009			Total annual actual	Comparison annual
	JAN actual	FEB actual	MAR actual		
Cost [$]	1,989	1,987	2,500	34,358	345,718
Consumption [kWh]	10,516	10,506	11,686	173,996	173,996
Avg cost per kWh	0.19	0.19	0.21	0.19	0.19
Energy cost/rentable SF	0.08	0.08	0.1	1.41	1.87

According to ASHRAE Standard 90.1-2010 (ASHRAE Standard 2010), the lighting system comprehended LED lamps in all the workstations and further optimization results were reached by installing occupancy sensors and daylight dimming controls.

4.2 *Economic and Environmental Benefits*

Thanks to the possibility to know the retrofit project and the operational costs, it is possible to analyze the life-cycle assessment of the intervention at Empire State Building.

In despite of the beginning costs of $4,624,262, that is higher than a traditional best quality office, the amount of the investment is going to pay for itself in 5 years (ROI less than 5 years). The project also benefited from the NYSerda (New York State Energy Research & Development) grant by $20,527, achieving a net gain of $492,869 (Table 3)

Another issue to consider in retrofit interventions is the indoor environmental benefit provided by HVAC improvement and specific comfort optimization strategies. Variable Air Volume diffusers allowed to bring additional outdoor air when necessary for high density zones. Specific attention was paid to the environmental quality of materials and resources such as carpeting, paints, adhesives, wood furniture. The indoor air quality was also guaranteed by high performance filters (MERV 13). Following the LEED for Commercial Interior guidelines also the water use was controlled and reduced by 40 %, providing high water efficient equipment.

The global environment benefits of Skaska office space retrofit is translated into a carbon footprint analysis. This analysis showes an equivalent CO_2 emission reduction by almost 80 t per year[1] (Table 4).

[1] Considering the New York City conversion factor of 0.86 lb CO_2/kWh.

Table 3 Project cost analysis summary

Total project cost	
High quality office budget [$]	4,413,404
Actual costs [$]	4,624,262
LEED premium [$]	210,858
Energy saving (NPV for 15 years) [$]	683,200
NYSERDA grant [$]	20,527
Net positive [$]	492,869

Table 4 Environmental impact of the project: carbon footprint calculation

Carbon footprint analysis	
Annual kWh (Traditional high quality office)	326,595
Annual kWh (@ ESB, 32nd floor office)	141,383
Annual saving [kWh]	185,212
NYC CO_2 footprint for electricity	1.72 kg/kWh
Carbon footprint reduction [tons/year]	683,200

5 Conclusions

In this chapter an integrated assessment of building energy upgrade is proposed considering several aspects that necessary interact within this issue. This contribution deals with a preliminary technical explanation about what building retrofit is, followed by an evaluation of the most common technical practices and innovative solutions. Also a global economical assessment is reported, specifically concerning market barriers and typical barriers also related to the current peculiar economic global situation. The purpose of this integrated analysis is to provide a method for evaluating and choosing the most fruitful global energy upgrade strategy with respect to different variables. This assessment method could provide a flexible tool for guiding the communication between different actors of the integrated process. The project team of the building energy upgrade intervention has to be formed by technicians, operators, designers, stakeholders, etc. The highest barrier against the building energy improvement success is often represented by the huge gap between these different skills we are trying to link following the proposed approach.

Given the huge environmental pressure, the reduction of the environmental pressure attributable to the built environment through this kind of integrated strategies is becoming always more relevant. Also, considering the economic global crisis, we analyze in particular no-cost and low-cost procedures for optimizing energy saving through operations and management strategies.

Also the case study represents a very useful prototype of integrated design for existing building energy upgrade. In facts the Skanska office space at the Empire State Building could became an useful example for guiding future improving interventions by integrating the energy approach with the indoor comfort issue and the economical and environmental constraint.

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