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Managing energy retrofit of acute hospitals and community clinics through EPC contracting: the MARTE project.

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Abstract

Acute hospitals and community clinics contribute to energy consumption and have a negative environmental impact. This is mainly due to the age of the buildings, a poor level of energy efficiency and a basic maintenance plan. Owing to the very limited money available for public administrators, Energy Performance Contracting (EPC), involving an Energy Service Company (ESCo), can provide the capital needed for investments aimed at increasing energy efficiency. In this paper three acute hospitals and two community clinics in Italy are analyzed prior to EPC development in order to assess the economic feasibility of retrofit strategies. The outcome of energy audits carried out in 2014, the analyses of consumption measured over the last 3 years, and the assessment of use profiles were all considered for the development of models to break down the overall consumption and to assess potential savings. Recommended improvement strategies include better insulation in envelopes, enhancement of mechanical and lighting equipment, use of renewable energy, better regulation of systems. Finally, payback periods for the most likely scenarios were evaluated.

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Keywords: EPC; Energy Performance Contract; Energy audit; Hospitals; Energy Efficiency.Introduction

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1. Introduction

Buildings are responsible for a considerable amount of overall energy requirements and greenhouse gas emissions. The non-residential field is a huge contributor, due to combined heating, cooling, ventilation and lighting loads.

Nomenclature

EPC	Energy Performance Contract
ESCo	Energy Service Company
CHP	Combinated heat and power / cogeneration
EP_{gl}	Global energy performance index (EP_h+EP_w) [kWh/(m^2·year)]
EP_H	Energy performance index in the heating season [kWh/(m^2·year)]
$EP_{H,L}$	Target energy performance index in the heating season [kWh/(m^2·year)]
EP_w	Energy performance index for domestic hot water production [kWh/(m^2·year)]
GHG	Greenhouse gas [kgCO_2/year]
PBP	Payback period [years]
η_{gl}	Heating system global efficiency [-]
S	Overall surface of the envelope [m^2]
V	Overall conditioned volume [m^3[
S_u	Internal floor area [m^2]

For this reason, European Commission guidelines recommend energy refurbishment as a priority for the reduction of energy needs and greenhouse gas emissions. One of the targets of the European Directive 2012/27/UE is to retrofit 3% of the existing public stock, while upgrading it to current legislation [1]. Several actions in favour of the Energy Performance Contracting (EPC) market in Europe have been put into practice, e.g. within the Intelligent Energy - Europe (IEE) programme. ESCos have been identified as key players in the implementation of EPC investments. In fact, EPC is an arrangement between any beneficiary and a provider (e.g. an ESCo), where investments in energy efficiency improvement are repaid in relation to the achievement of a pre-determined energy efficiency improvement [1]. Thus, technical and economic risks are transferred mainly to the provider, and the beneficiary (e.g. public administration) is involved to a lesser extent. Furthermore, the principle investment is made by the ESCo, whereas the beneficiary is only responsible for paying a regular fee, which is expected to be no higher than the total amount of the real operational costs. This is the most common case, which is valid when the payback time on the investments is shorter than the contract duration. If the payback time is longer than the contract duration, the beneficiary will pay more than the real operational expenses but will reap the benefits of energy savings either throughout the duration of the contract (if it pays less than the operational costs), or soon after the end of the contract.

These issues have already been considered by the scientific community, that assessed retrofit sustainability in the non-residential sector [2-4]. The Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) drafted an accurate analysis of contractual issues [5]. Other studies [6] focus on the acceptance and success rates of this approach in Europe.

One of the most important steps in EPC is the planning and implementation of a detailed energy audit [7-8]. Buonomano et al. [9] carried out dynamic simulations of 4 blocks of an Italian hospital, and showed that the highest savings could derive from retrofitting the heating and air ventilation systems. Ascione et al. [10] opted for refurbishment of the building envelope. Saidur et al. [11] suggested slight improvements to systems, such as the adoption of variable speed drives.

This paper will describe the energy audit of 5 hospitals, all targeted for setting up an EPC tendering procedure. Three are acute hospitals, hence quite big, while two are community clinics, and are therefore subject to changeable needs, services and profiles of use. These case studies are involved in the MARTE project ("Marche Region Technical assistance for healthcare buildings Energy retrofit"), funded by the EU commission within the Intelligent Energy – Europe programme. The main objective of this project is to survey innovative financing strategies to foster energy efficiency investments, e.g. combining MLEI (Mobilising Local Energy Investment) assistance and regional funds ROP – ERDF (Regional Operational Programme - European Regional Development Fund)

2. The MARTE project case studies

The general aim of the Marche Region is to provide MLEI – PDA (Project Development Assistance) to mobilise financing for sustainable energy projects in healthcare buildings. The beneficiary in this case is the public company ASUR, which owns a total of 280 buildings. The project plans to mobilise 15 million euros in retrofitting for the EPC pilot project that is developed by MARTE. The project aims to create new business models for energy efficiency intervention that can be replicated in other sectors, and applied to other fields including regional and local authorities. The five case studies, that belong to the MARTE pilot project, are listed in Table 1. Figure 1 shows some snapshots of the case study buildings.

Table 1. Climate zone, geometry and time of construction of acute hospitals and community clinics.

Id (City)	Climate Zone [Italian leg.]	Degree days	Number of floors	S_u [m^2]	V [m^3]	Ratio S/V	Time of construction
San Benedetto del Tronto	D	1593	8	36863	159422	0.27	1960s-1980s
Urbino	E	2545	8	21018	87238	0.38	1960s-1990s
Pergola	E	2264	6	8195	34026	0.43	1970s
Sant'Elpidio a Mare	D	1874	7	2360 (3444)	10580 (15239)	0.41 (0.32)	1970s-1980s
Petritoli	D	2058	5	2184 (3229)	10866 (16292)	0.56 (0.48)	1970s-1980s

Fig. 1. Pictures of (a) San Benedetto del Tronto; (b) Urbino; (c) Pergola; (d) Sant'Elpidio a Mare and (e) Petritoli.

3. Materials and methods

3.1. Data collection

Data were gathered so as to be able to perform all the energy and economic evaluations suggested by EN 16247-2 paragraph 5.3, "Collecting data" [8]. Energy consumptions and costs were derived from the monthly bills of energy carriers (electricity and methane). The audit considered the previous three years whenever feasible, or at least two years in the worst case. In order to consider all the parameters relative to size, technical features of the buildings, related equipment and physical performance, on-site surveys, interviews and as-built documentation were collected. In the few cases for which data were not available, an estimation of the missing parameters was based on information provided by standards [12,13], by the technical literature, technical manuals and the expertise of the auditors. Occupancy figures, plant operation and constraints to be accounted for while planning retrofit intervention were mainly inferred from meetings or interviews with building management staff and technicians.

3.2. Evaluation of the energy behaviour

The energy behaviour of the three acute hospitals was estimated by means of a two-step process:

1. data collected on real energy consumption were used to calibrate the energy models, that were called the benchmarks;
2. the benefits deriving from several retrofit hypotheses were assessed by means of the energy models developed in the previous step, and calculated as the difference between the benchmark consumption and the (lower) energy consumption after retrofitting.

The two community clinics required an intermediate step, in addition to those already mentioned:

1. development of the preliminary benchmark, as explained above;
2. projection of the benchmark considering the future arrangement of the buildings, because currently some of the clinic's volume is not heated as it is unused, but in the near future (before signing the new EPC) these rooms will be dedicated to health care activities, mainly concerning nursing clinical practice. This second step led to the development of a benchmark for the envisaged use of the buildings, called "estimated benchmark" in the following text;
3. estimation of the benefits deriving from several combinations of retrofit intervention, similar to point 2 in the process described for the acute hospitals.

In conclusion, three benchmarks were set for the acute hospitals and two estimated benchmarks were set for the community clinics. The benefits achieved by retrofitting were estimated as the energy saved with respect to these benchmarks.

As monthly energy consumption data about the audited buildings were available, the energy models to define the benchmarks were developed by means of MC4Suite2013, that is CTI (Italian Thermotechnical Committee) validated software. It is compliant with Italian technical standards UNI TS 11300 parts no. 1 and no. 2 [12,13]. These standards concern design and calculation procedures for the simulation of heating and hot water production systems. The choice of this simulation tool is in line with Italian legislation on energy auditing [14] and energy labelling [15], that does not set real constraints, but allows the auditors to choose whether standardised or dynamic simulation tools work better, depending on the purpose of the energy audit. The standardised simulation tool used in this case was deemed accurate enough for a comparison with the collected energy consumption data. Furthermore, as MC4Suite2013 is very popular with Italian ESCos dynamic simulation tools (such as Energy Plus and TRANSYS) were not considered in our application.

The energy assessment performed for the five buildings encompassed both winter and summer conditions. Firstly, energy figures for heating and hot water were measured in terms of EP index, that is kWh/(m^3·year), referred to the gross volume of the building. The energy consumption was then translated into primary energy. This conversion factor (C.F.) is derived from the knowledge of the amount of energy produced by a unit volume of methane (C.F.=1) and by a kWh unit of electricity (C.F.=2.34).

As a consequence, the energy reduction brought about by retrofitting was first assessed in terms of primary energy, and was subsequently split into the amount of cubic meters of methane and the amount of kWh of electric energy saved per year. A knowledge of the unit cost of both fuels allowed the cost savings to be derived straightforwardly.

3.3. Economic analysis

The economic analysis involved two steps: the development of the estimate summary and the assessment of the expected payback period for each candidate retrofit combination hypothesised within the analyses described in paragraph 3.2.

A quantity survey was carried out for all the retrofit combinations, including the breakdown of each retrofit scenario into activities and the estimation of the dimensions of each activity. The accuracy of this step was typical of preliminary drawings. Unit price cost data were then applied to the dimension of each activity, so that the total pricing could be worked out. Cost data were taken from the most popular published source in our region, which is the official database drawn up by the Marche regional authority, called "Prezziario Regione Marche 2014". Those activities for which published unit price costs were not available, were estimated by means of the average between two or more quotations provided by suppliers or vendors. As a result of this process, an estimate summary was determined for each type of candidate retrofit in the following way: the first column contains the description of activities; the second column includes the results of the quantity survey; the third column provides unit prices, and the last column indicates the total price of the activity. The value for each type of retrofitting is obtained by totalling the last column.

Maintenance costs were not considered, because renovation of equipment must imply lower maintenance costs in the future, that will lead to a conservative estimate of the payback period. In fact, a simple payback period was estimated (PBP), because real interest rates will depend on the source of the money for investments. Therefore, the value of each retrofit action was divided by the annual economic savings referred to the same action, given by the result of the calculations described in paragraph 3.2. The unit price of fuel and electricity was assessed as the total cost of fuel and electricity throughout the period which the energy audit refers to, divided by the amount of fuel and electricity actually used.

4. Results and discussion

The data regarding the benchmarks of the acute hospitals and the community clinics are summarised in Table 2. In the case of community clinics, the figures in brackets refer to the final benchmarks, i.e. those concerning future scenarios, while all the other numbers are relative to the present state. It should be noticed that acute hospitals have higher unit energy consumption, probably due to the greater number of hours of daily occupation. This is also the reason why future heating consumption of community clinics is expected to increase.

Table 2. Results of the benchmarking analyses.

Id	Methane [kWh/m^3·y]	Electricity [kWh/m^3·y]	EP_H [kWh/m^3·y]	$EP_{H,L}$ [kWh/m^3·y]	EP_w [kWh/m^3·y]	η_{gl} [%]
San Benedetto del Tronto	57.2	26.0	30.3	7.4	2.4	62.3
Urbino	69.2	40.7	68.7	13.6	3.7	60.7
Pergola	62.7	18.3	59.3	13.3	1.9	73.7
Sant'Elpidio a Mare	49.0	12.9	34.0 (39.2)	14.4 (13.1)	19.4 (9.8)	45.8
Petritoli	41.4	7.5	33.3 (52.2)	10.9 (9.4)	10.9 (6.3)	59.0

Table 3 lists the most convenient combinations of retrofit intervention. Whereas acute hospitals will be retrofitted by means of extensive renovation activities, such as improved insulation of envelopes, replacement of windows and of the heating plant, community clinics will be retrofitted using low cost actions, such as enhancement of the regulation system, integration of solar panels, partial replacement of the worst windows, partial replacement of lighting fixtures with a Digital Addressable Lighting Interface (DALI) control system. As a result, the percentage reduction in energy consumption (i.e. the amount of energy saved with respect to current consumption) was split between thermal and electric, because the latter contribution is comparable to the former. Each combination was selected as the result of previous assessments regarding the convenience of the single actions making up the various combinations, and as a result of technical feasibility analyses.

Table 3. Post-retrofit scenarios relative to the five hospitals.

Id (City)	actions	EP_H [kWh/m^3·year]	energy reduction [%]	initial investment [k€]	cost reduction [k€/year]	GHG reduction [kgCO_2/y]	PBP [year]
San Benedetto del Tronto	retrofit of whole envelope and heating generation and control system	7.60	77	4600	358	771000	13
Urbino	retrofit of whole envelope and control system. Starting CHP.	15.44	79	3150	218	813825	15
Pergola	retrofit of whole envelope and heating generation and control system	12.40	79	2180	110	315000	20
Sant'Elpidio a Mare	window replac., new heating system regulation, lighting and solar panels	19.4	(heating) 33.9% (electric) 47.4%	370.4	32	120384	11.6
Petritoli	window replac., roof insul., new heat generation and regulation, lighting and solar panels	20.9	(heating) 49.8% (electric) 32.4%	370	39.8	127730	9.3

5. Conclusions

The assessment presented in this paper showed that although the analysed buildings require enormous amounts of energy for space heating, domestic hot water (DHW), and other electric supplies, suitable refurbishment can enhance their performance and reduce their energy consumptions by up to 77% in those cases where “high cost investments” (acute hospitals) were hypothesised. Savings are no lower than 35-40% for the “low cost investment” refurbishment actions (community clinics). As far as the first kind of intervention is concerned, despite the huge expected energy savings, the PBP is quite long (15-20 years). As regards the second type of action, the PBP (9-11 years) is almost compatible with the duration of Energy Performance Contracts. For that reason and in order to make the investment convenient from the economic and financial points of view, it must be supported by some form of economic incentive. One of the most popular types of third party support involves public incentives, which could be sized either on the effective energy reduction (white certificate) or on the environmental benefits that can be pursued (i.e. reduction of GHG).

The method proposed in this paper was based on regular energy analyses, that can easily be repeated and verified, so that any candidate bidding for an EPC tender can quickly evaluate the benefits deriving from any other variation in the basic proposed investment. Despite that, oversimplification is not suitable for this kind of analysis, because it could lead to the inability to properly consider some services.

As a general remark, buildings potentially suitable for retrofitting and energy requalification should be equipped with a monitoring system for energy and thermal parameters, so as to speed up data collection for energy auditing procedures. The same system would also be useful for monitoring and controlling the real performance of renewed systems.

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