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RETROFIT OPTIONS FOR INCREASING ENERGY EFFICIENCY IN OFFICE BUILDINGS - METHODOLOGY REVIEW

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Abstract

Portuguese Buildings represent 35% of primary energy consumption in 2006, with non-residential sector representing almost half of this number globally and around 65% in Lisbon city. Expected to grow 5% yearly in this period, non-residential buildings rehabilitation is a great opportunity for energy rehabilitation for a stock of 800.000 buildings needing medium to high interventions. For this task to be successful it is also urgent that procedures consider an accurate technical framework, where existing technologies and best case-studies can be considered, in order to drive passive measures retrofitting forward. This paper presents an overview of a methodology development which pretends to include the energy component in rehabilitation schemes with an integrated and comprehensive analysis, achieving all those directly involved in the building process (owners, consumers, public bodies, construction and project design industry) as well as new important players such as ESCOs.

Keywords: methodology development; building characterization; modeling; monitoring; retrofitting market; passive retrofitting strategies;

Buildings Energy Use

The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased reaching figures between 20% and 40% final energy in developed countries, and has generally exceeded the other major sectors: industrial and transportation (Lombard, 2008). A rising demand for building services and for higher comfort levels combined with the increase in time spent inside buildings suggests that this upward trend in energy demand will continue in the future. EIA foresees that energy consumption in the built environment will grow by 34% in the next 20 years. In 2030, energy consumption attributed to residential and commercial sectors will be respectively 67% and 33% (US-DOE, 2006).

As a consequence, energy efficiency in buildings is today seen as a prime concern globally. The European Commission has estimated for buildings, a potential of cost-effective savings around 30% by 2020 (see Table 1) (Lombard, 2008), materialized through instruments such as the European Energy Performance of Buildings Directive (EPBD) and National Energy Efficiency Action Plans.

After starting up Buildings Certification System, Portugal recently approved its own Action Plan with measures such as “Renew House & Office” or “Office Plus”, where by taxes reduction and subsidies promotes efficient construction and retrofit (windows replacement and insulation among options).

On the city scale, Clinton Climate Initiative (CCI) recently announced the Energy Efficiency Building Retrofit Program working with city governments, energy services companies, financial institutions and trade organizations to help reducing building energy use (Holness, 2008). Lisbon is involved and is also self-committed to reduce its energy consumption by 6.4% until 2013 (Lisbon Environment-Energy Strategy) (Tirone, 2005).

Introducing Portuguese figures, Buildings represent 29% of the final energy consumption (35% primary) in 2006 (DGEG, 2008), with non-residential sector growing rapidly, representing almost half of this number globally and around 65% in Lisbon city.

Sector	Energy Consumption (Mtoe) 2005	Energy Consumption (Mtoe) 2020 (BAU)	Energy Saving Potential 2020 (Mtoe)	Full Energy Saving Potential 2020 (%)
Residential	**280**	**338**	**91**	**27%**
Tertiary	**157**	**211**	**63**	**30%**
Transport	332	405	105	26%
Industry	297	382	95	25%

Table 1. Estimates for full energy saving potential in end-use sectors (EC, 2006)

Buildings Rehabilitation

During last century, new buildings prevailed on the construction market, disregarding existing construction, so there is presently an urgent need for rehabilitation (medium to very high interventions) of more than 800.000 building units (15% of the stock). Closely related to energy retrofitting possibility, building rehabilitation market is expected to grow from 28% (2005) to 41% of total construction by 2020, mainly because of non-residential buildings, as this market is expected to grow 5% yearly in this period (AECOPS, 2008).

One of the barriers to upgrading existing buildings is the availability and cost of capital to an owner or lessee. The economics of borrowing long term (25 to 30 years) capital for improvements may be less attractive than other short-term investments, in spite of rising energy costs.

As a result, many existing buildings are starting to be updated through energy performance contracting programs established with energy service companies (ESCOs), which finance and implement energy-efficiency measures for a share of future energy cost savings (Holness, 2008).

So, with this broad field of analysis, it's necessary for this task success that procedures consider an accurate technical framework, where existing technologies and best case-studies can be considered. This is where the chosen methodology could be of great importance for the audience we're referring to.

Focusing on target audiences, ESCOs are likely to push the passive retrofitting measures forward, therefore, they are a privilege target audience for this methodology, besides all those directly involved in the building process: owners, consumers, public bodies (from municipalities to energy agencies), construction and project design industries.

All the above political and market incentives to improve the energy performance of buildings, together with energy prices and a 'greener' society, are boosting more and more the awareness of buildings energy rehabilitation. And it is starting to be seen as an opportunity for business, with proven cost-effective investments (see Figure 1).

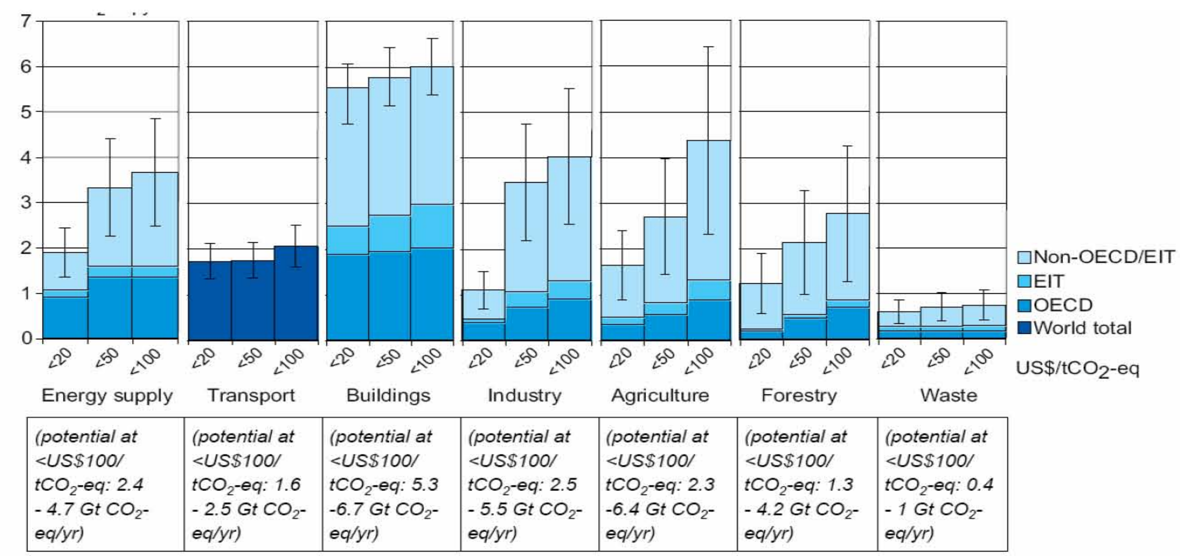

Figure 1 - Estimated sector economic potential for global CO2 mitigation for different regions as a function of carbon price in 2030 (Levine, 2007)

METHODOLOGY EXAMPLE
Focusing on Portuguese Offices Buildings Sector

During last century, tertiary sector role in society has grown impressively. Associated with the growth of non-domestic buildings there has been an increasing demand for energy where office buildings can be underlined for its specific characteristics (high occupancy, high internal loads), and weight (represent 25% of commercial buildings in Portugal (AECOPS, 2008)). Confirming this, across Europe, the office building retrofitting market has seen considerable growth over the last years. Several reasons can explain this (Caccavelli, 2002):

- Short "service life" (adaptation to requirements on working conditions);
- User's requirements have considerably changed during the last decade (office equipment, communications, automation, quality of use and comfort);
- High market standards due to the oversupply of office space; buildings that do not offer all the amenities for comfort and flexibility, are difficult to sell or rent;
- Office buildings are classified amongst the buildings presenting the highest energy consumption (200-600kWh/(m2.year) of conditioned floor space); they need to verify minimal standards due to New Buildings Certification System (Portuguese System limit around 140kWh/(m2.year));
- Many of this buildings are publicly owned, potentially facilitating the process of intervention;
- Mentioning business offices, businesses tend to be more “rational” than homeowners when they see profit, and do not need such investment incentives;
- Problems mostly related to thermal comfort in summer, which are predicted to increase.

Office buildings, mainly those constructed in last part of the century, were designed to isolate the internal conditions from the outdoor climate as far as possible, at the cost of high energy consumption. Thermal and visual comfort as well as the air quality was assured through extensive technical building services for heating, ventilation, air-conditioning and lighting (HVACL). The high investment and running costs were accepted to ensure that even extreme indoor conditions caused by generously glazed building envelopes could be controlled (Voss, 2007).

However, the present approach is distinct, as investments in cost-effective retrofitting measures are being considered for the same buildings, with companies starting to face inevitable energy rising costs.

Within this approach, productivity losses should be analyzed as well. The correlations between the improvement of workers comfort satisfaction and companies’ rising productivity are demonstrated, and the projected gains could be very large. In most nonindustrial workplaces, the costs of salaries and benefits exceeds energy, maintenance, and annualized construction costs or rent, by approximately a factor of 100 (referring to year 2000). For that reason, productivity gains could serve as a strong stimulus for energy efficiency retrofitting measures that simultaneously improve the indoor environment.

Identify Rehabilitation Needs

Especially important has been the intensification of energy consumption from HVAC systems, which has now become almost essential, as well as a spread in the demand for thermal comfort, considered a luxury not long ago. It is the largest energy end use both in the residential and non-residential sector, comprising heating, ventilation and air conditioning. For non-domestic buildings, according to EIA estimations, HVAC energy consumption is around 40% of total final energy, with offices reaching numbers of around 50%, as well as in US or EU (Lombard, 2008). Moreover, predictions indicate a massive growth in energy consumption and conditioned area in the EU during the next 15 years, increasing approximately in 50%. The other key energy end uses in offices are lighting and appliances, adding up together with HVAC about 85% of the total (see Figure 2). Building type is critical in how energy end uses are distributed and in their energy intensity, that’s why it is essential to develop independent studies by building types.

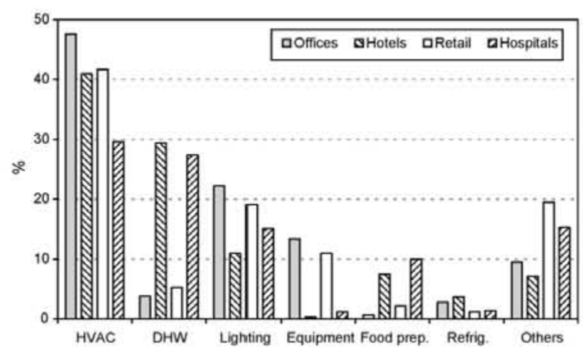

Figure 2. Consumption by end use for different building types (Lombard, 2008).

Focusing on HVAC, although buildings with air conditioning maintain, in general, an objectively better indoor climate, they are subjectively rated lower than naturally ventilated working conditions by the majority of persons enquired. With an increasing fraction of office buildings being constructed or retrofitted, the logical trend is that buildings change complete isolation from the weather outdoors to a kind of moderate interaction with outdoor conditions, benefiting from that. This approach is incorporated in 'lean building' concept that: 'even when the weather outdoors varies greatly, the indoor conditions remain within a well-defined comfort zone, which meets the expectations of the occupants' (Voss, 2007).

Methodology Design and Tools

The objective is to create a methodology that can lead to new business opportunities and integrate all building sector players focusing on the best available passive solutions for offices energy retrofitting. Lisbon city is the initial case-study, but as mentioned ahead, the objective is to spread the scope to other compatible contexts. Constructing the methodology, below is the description of main steps (see Figure 3):

Part I: Characterization of existing building stock

I.1 Characterize existing building stock

The first goal will be to characterize a representative sample of site buildings (Lisbon has 4 typical and representative buildings structures).This characterization permits to follow to thermal characteristics analysis of the associated construction materials for each typology, for posterior thermal modeling purposes. Simultaneously is evaluated the general level of conservation (and general rehabilitation needs) by using municipality data (urban scale mapping and diagnostic tools available for Lisbon). Here are presented other building characteristics needed for the posterior detailing modeling:

- Building weight (thermal mass);
- Materials thermal transmission coefficients (U);
- Materials leakage levels (infiltration);
- Glazing ratio / Solar protection (glazing, shading);
- Orientation / Solar gains;
- Air Change (Infiltration, Ventilation);
- Type and characteristics of HVAC system;
- Design indoor-temperature;
- Occupant, Lighting and Equipment type and density;
- Operation times;
- Internal gains (occupants, equipment, lighting);
- Urban Climate; Urban Morphology

I.2 Thermal Modeling of the identified typologies of the representative sample of City buildings using most suitable thermal Energy Simulation Models such as EnergyPlus or ESP-r.

A comparison between the available software on the market using the global sample of representative buildings is being done, and then the best set of models and tools will be chosen to accomplish the office buildings task.

Part II: Monitoring Data and Model Calibration

II.1 Detailed Consumption Monitoring for Model Calibration - Detailed energy consumption data from field monitoring of the selected buildings and existing "monitoring databases"

Having modeled the object of analysis, it is necessary to validate those data, and calibrate the model through measuring/monitoring of the typified buildings in the field (data from Demand Side Management research group work). Some compatible monitoring studies realized and in progress (and available on the market) could be helpful, such as:

- EL-TERTIARY (Monitoring Electricity Consumption in the Tertiary Sector);
- ENER-IN-TOWN (Energy Consumption in Municipal buildings);
- ODYSEE (Energy Efficiency Indicators in Europe).
- REMODECE (Residential Energy Monitoring in Europe);

II.2 Thermal Modeling of the monitored buildings and model calibration with collected data

The simulation results are compared with the values obtained from characterized data ensuring the validation of any used simplifications and assumptions. This data correlation is of the most importance to have accurate figures of energy consumption, from consumption profiles to occupation rates, in order to have a solid base to work on potential impact.

Part III: Identifying integrated energy retrofitting best options

III.1 For the chosen Best Available Technologies (BAT) is examined the direct energy impact trough thermal modeling, acquiring energy savings potential.

Options like insulation and thermal mass, aspect ratio, color of external surfaces, shading, window systems including window area and glazing system, natural ventilation and different outdoor air control strategies are among the examined.

III.2 Identifying energy retrofitting measures facing energy inefficiencies and considered general rehabilitation needs (construction degradation and pathologies, functional obsolescence of building services and environmental indoor quality).

III.3 The selected measures are submitted to a multi-criteria analysis where standard economic cost--effectiveness is completed trough a building materials LCA and evaluation of measure expected efficacy. The already tested decision-making tool TOBUS (Caccavelli, 2002) could be a strong source for this last purpose.

Part IV. Methodology development for replication potential analysis

Methodology Results are materialized from the integration of the best energy retrofit options, after having the clear perspective of the problem and its variables. In this final phase, the purpose is to integrate this methodology in a broader scale multi-objective approach of the global energy intervention in the building. This broad analysis must include active solutions such as microgeneration/trigeneration, enhanced building energy management systems or devices efficiency improvement, and is part of the joint work within the MIT|Portugal Building Technology Research Group Work.

As an integrative methodology, it should incorporate a necessary potential of replication to other contexts that could spread out the methodology for implementation at a larger scale (from the initial scale of Lisbon city). The objective is to establish clear procedures that could contribute to the application of this models and tools to different cities and neighborhoods.

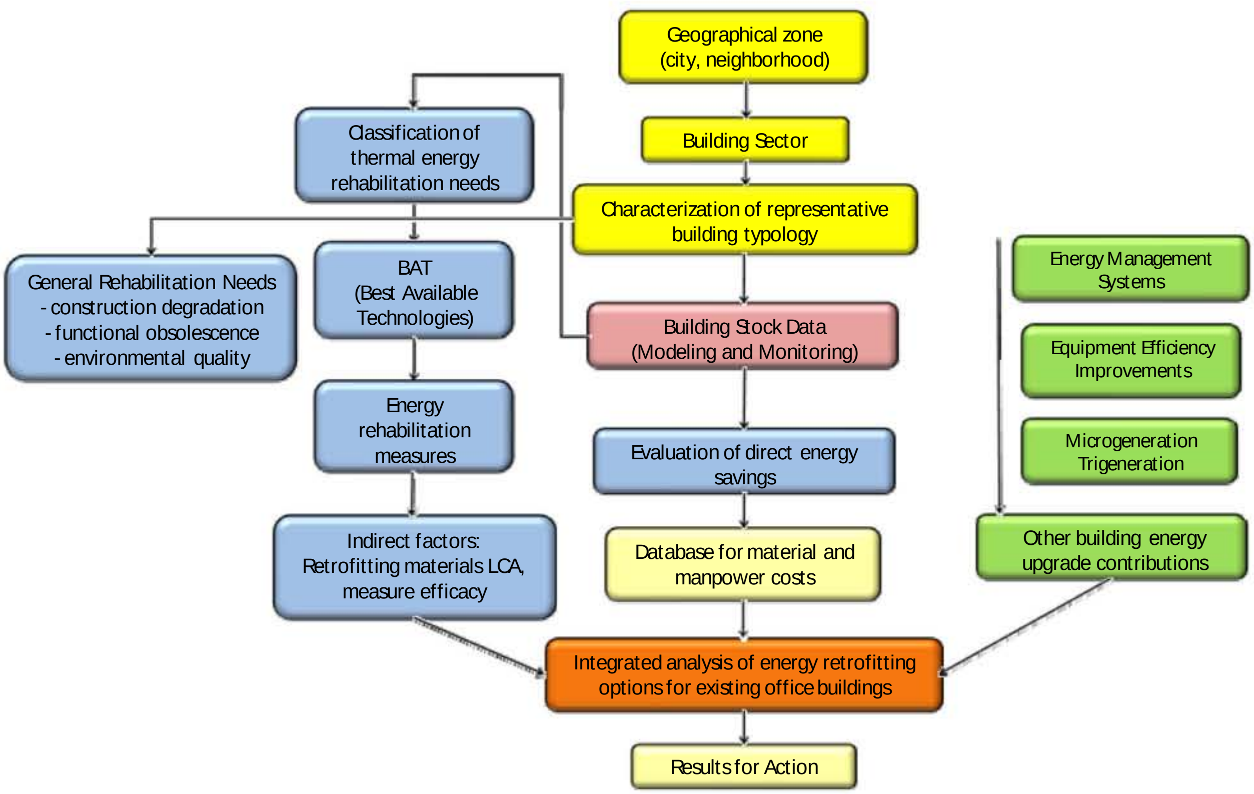

Figure 3. Energy rehabilitation methodology (Adapted from Calau, 1999)

Applicability Constrains

- 'The saved Watt (Negawatt) is always the best one', but many times not the easiest one. Passive measures are sometimes harder to implement due to less public exposure facing active measures such as micro-generation integration or efficient HVAC systems. This happens mostly if companies want to sell a 'green' image, but doesn´t mean they cannot work together for an optimal result.
- Electricity prices are still subsidized (other sectors like transports are more willing to change because of taxed energy prices). Also the incentives for distributed generation are many times more interesting than passive measures ones.
- Economy crisis (companies can't afford extra costs). Here the ESCO concept could be applicable by the introduction of retrofitting costs on energy performance contracts.

Cooperation

At some stage, the work will be done, in cooperation with industries and local municipality. With this cooperation, the objective is to facilitate the applicability of the methodology in the field, and help the implementation of a new energy services company at the urban scale. This industry partner works with the goal of improving energy efficiency in buildings, focusing among other options in the integration of passive solutions for energy efficiency in buildings. Inside the "Energy Services" new paradigm, the integration of retrofitting solutions through this methodology will be an added value for this new business model.

Conclusions

The majority of the existing buildings is far away from an optimal scenario and is responsible for significant energy consumption. The presently favorable conditions for rehabilitation programs focused on energy component, create a good opportunity to energy retrofitting.

This methodology development pretends to include the energy component in rehabilitation schemes with an integrated and comprehensive analysis. The detailed variables and data study, the cross cut perspective of energy retrofitting and vital audience proximity (energy services industry, municipality, sector players), gives a fair potential for applicability and replication of the methodology to a larger scale.

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