Automation of Passive Processes: Energy Efficiency in Adjusting to the Environmental Constraints

Bruno Marques and Luís Pestana Baptista

Abstract—**Nowadays, the promotion of sustainable architectural solutions represents an important promotion and development highlight, although destined to a very specific target audience – the ones interested in the environmental aspects and with high purchasing power. However, the Sustainability and Energy Efficiency issue is universal and can only get a satisfactory answer by the society widespread involvement.**

Despite the population sensitivity to these questions, the fact is the existing architectural solutions are too far apart from the middle class expectations, investment power, rhythm and everyday way of life.

Thus, we explore the recovery of buildings as a more economically viable option, proposing the development of a Domotic system specifically designed for the house Passive Processes promotion, which will ensure optimal comfort conditions, efficiency and the constant building management and its processes.

Index Terms—**Automation, building rehabilitation, domotic, energy efficiency, inova domus, passive processes.**

I. Introduction

When considering an intervention, whether a new construction or a rehabilitation project, Architecture is based on good construction planning and practices, aiming to establishing a symbiosis between the available resources and the user's needs and expectations.

Current modern societies, the Portuguese in particular, are involved in a severe economic and social crisis, which has resulted in a generalized funds decrease, restricting the investment and development opportunities. The stagnation of the constructive sector, dragged by the middle class loss of investment power, is a clear example of this situation, resulting in the fact that most families' can´t afford to buy a house fitted to the current housing standards.

Besides that problem, the evolution of the rhythms of life and habits of modern societies caused that the traditional methods and the housing maintenance processes, used to ensure the comfort and health conditions, have been widely forgotten and replaced by mechanical equipment that represent significant energy expenditure and inadequate thermal needs.

To give Future to the homes of the Past, transforming them in dignified, quality buildings that configure an equal/more comfortable option than a new dwelling, resulting in more environmental, sustainable and financially advantageous solutions.

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Agreeing with the premise outlined by InovaDomus(Association for the Development of the House of the Future) [1], that the recovery of old buildings is currently the most economical and sustainable solution to address the housing needs, we believe that the basis to the rehabilitation of these buildings should be the implementation of the Passive Architecture principles (measures representative of a good architecture), whenever possible avoiding the resource to mechanical equipment and promoting the use of the natural means and the house sustainability.

When referring to "environmentally and financially advantageous sustainable solutions" we must consider the entire housing life cycle, including use and operation duration with the proper comfort conditions and their resource consumptions.

In this context, it wouldn´t make sense to recover a building to the current/future housing patterns, followed by the application of last century's energy consumption configurations.

This becomes even more evident when considering the current and expected annual energy costs increasedue to high consumption andfossil fuels shortage/price.

Therefore, regarding energy efficiency, this proposal also sets an optimal solution since, currently, the implementation of Passive Architecture principles and techniques notes very significant energy savings. In fact, when compared with the annual energy spending of an "ordinary architecture" house, a properly designed building features an efficiency gain that can reach up to 70% of the annual expenditures.

II. Adequacy to Environmental Constraints

Most practical cases or studies about building's or test cell thermal performance present a similar operating / driving test scheme:

1) Generally, the tested compartments are exposed to the effect of environmental conditions, either under different orientation or conditioning elements, recording the data throughout the day (or days) while practicing a static behavior (without adjustment of the protective elements);
2) In some cases, the energy efficiency test takes place together with the evaluation of the auxiliary power required to achieve and maintain thermal comfort. In these examples, the adequacy of the protection elements is set aside, opting for the resource to active conditioning systems;
3) In specific cases, when one intends to test a particular item or system, we encounter cases of automated elements that respond directly to some environmental

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conditions changes, however without considering this measure impact on the behavior or on the thermal performance of the dwelling in the following hours.

When analyzing the thermal behavior of a house or, in a more specific case, of a wall, we know that the response to the environmental conditions isn't always the same, since these also present changes throughout the day.

Let's consider the case of house outer wall. Regarding the composition of this element, we can immediately assess its behavior – knowing the materials that compose it, their thickness and placement, we can obtain the inertia value and the thermal conductivity of the element.

With the use of a specific calculation, we can also estimate its general behavior and impact on a building, establishing a behavior average, by using the predefined annual values of internal and external temperature.

However, the determination of the thermal performance with the resource to average annual temperatures creates timings in which the response of the elements to the real, substantially different and changeable daily conditions actually affect the thermal performance of the building; that is, as showed in Fig. 1, the transmission temperature through the walls has a different impact if we consider an indoor temperature of 21ºC with outdoor temperature of 5ºC (8:00 a.m.) or 15ºC (14:00 p.m.).

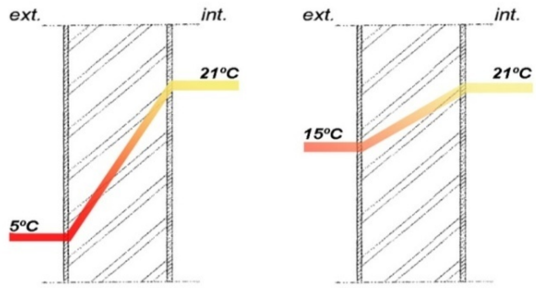

Fig. 1. Wall energy loss in the interior/ exterior temperature relation.

Although, in many cases, thermal inertia is able to counteract the impact of this situation, when considering the elements with traditionally little inertia (the most obvious are the glazed areas), responsible for most of the building thermal losses, as exemplified in Fig. 2, the difference in the external temperature value assumes an increased importance, resulting in higher energy losses or gains throughout the day.

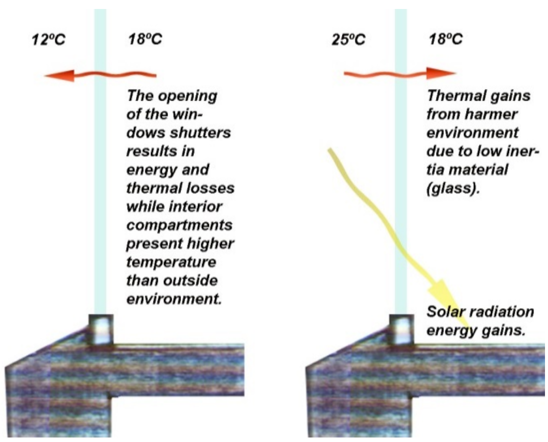

Fig. 2. Low inertia elements like glazed windows represent points of big thermal and energy transfers that are specially subjected to the relations and changes in environmental conditions.

Additionally, the heat transfer rate is not only affected by the temperature parameter, but also by humidity, air velocity and the solar radiation.

For example, as presented in Fig. 3, if we consider a single element, subject to the same temperature conditions but with differing amounts of moisture, its impact on the thermal behavior will be different since the material surface temperature would be lower than the actual air temperature [2].

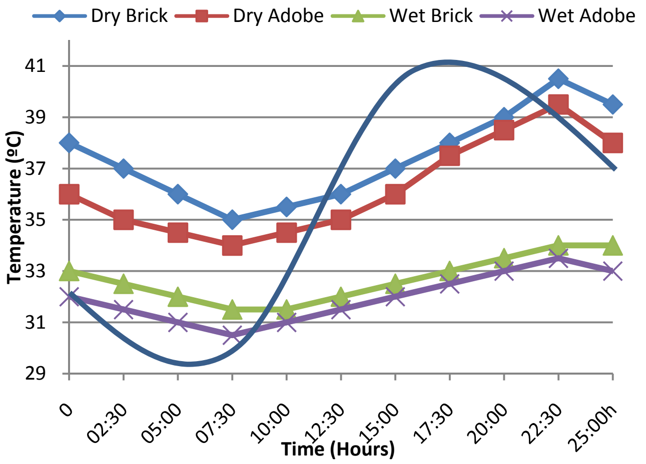

Fig. 3. Comparison of hourly variation of a room temperature when the adobe and brick structures are dry and wet.

Similarly, when consider the effect of wind on a certain element, thermal performance would by greatly affected by the effect of convection on the surface temperature, dissipating heat, cooling down the material and liberating the material acquired energy (phenomenon's that can be used towards or against the desired thermal behavior), thereby accelerating the thermal transmission effect.

Lastly, the existing formulas consider that the elements are subject to permanent actions when, in fact, such premise rarely exists. Actually, a base assumption when working with the weather is that, although we can establish a baseline behavior, reasoned by each zone climate usual, the adaptation to the variations throughout the day is essential for the proper use of the same .

Let's consider the example of the Thermally Optimized Lab-House (CTO) [3] – a project developed by the Oporto University's Faculty of Engineering, Mechanical Engineering Department – a representative study about passive thermal behavior design on a house in Portugal, were we have the application of the test schemes previously explained.

The CTO is a thermally optimized house which aims to balance and maintain the interior thermal comfort conditions along with the best possible energy management. The key objective is to take full advantage of the natural resources with minimum auxiliary energy consumption.

Intended to represent a traditional three bedroom typology house, promoting the concept as a valid housing alternative, it translates as a solution focused on environment and comfort, instead of focusing on a pure thermal behavior policy.

In this study, thermal performance and energy use registration were conducted several times per day during two years, while establishing two distinct operation modes:

1) During the first year, the house was monitored and maintained on a pure passive operating regimen, without recourse to any mechanical equipment;
2) In the following year, set to constantly maintain a minimum internal temperature of 18°C, while recording the auxiliary power load required to that purpose.

The results, presented in Fig. 4 and Fig. 5, confirmed the good thermal performance behavior of the building. In the first case, the internal temperature average was 15°C in the cooler months (January). In the second year, solar energy provided 45% of the energy required for domestic heating, which accounted to energy savings (in this function, compared to a "normal" house) of about 73% [4].

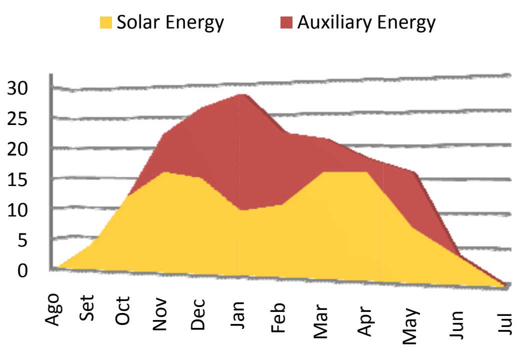

Fig. 4. CTO monthly heating demand and supply.

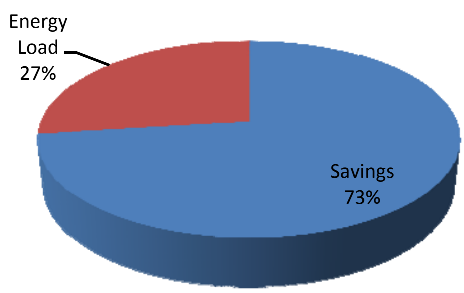

Fig. 5. Heating energy savings in comparison with a typical Portuguese house energy demand.

However, in both operating modes, the study indicates that the dwelling behavior / processes consisted in the full opening of the windows shutters, in the morning, closing them at dusk. All the other parameters and elements were kept static throughout the study.

Knowing that the material's thermal response is of variable behavior, through the impact of environmental conditions on their surfaces, we can deduce that the energy and the thermal performances of the house weren't the most efficient.

In this context, we propose that a vital step in improving the buildings performance and energy efficiency depends on the promotion of the principles and processes of Passive Architecture, performing the external and internal environmental conditions management uninterruptedly, while promoting the best behavior and the desired thermal comfort conditions.

However, such management is complex and displaced from most people lifestyle.

The attention to the environmental changes throughout the day is an often neglected aspect since, in most cases, the buildings are inhabited throughout the day (during the working days). Additionally, the calculation of the relation between losses and gains, relative to the outside environment, is very complex and time consuming.

Therefore, we believe that the development of a Domotic System, specifically designed to promote and manage the housing passive behavior, may provide the solution.

III. Domotic (Home Automation)

When choosing a particular architectural or constructive approach, we should always consider the society in which it will occur.

Historically, we can define two clear evolutionary concepts:

1) A western style, typically focused on mechanical, electronic and scientific solutions, with solutions that strongly rely on energy consumption;
2) A oriental style, turned to the nature and to the simple, traditional solutions, in great contact with the environment and with the spiritual.

Acknowledging both concepts benefits, our approach combines each style advantages. Adapting traditional low-cost processes and an heighten sense of relation with the environment, correctly formatted to the local reality, expectations and live-habits, we can achieve a naturally sustainable solution. Adding the standards, solutions and technological solutions of the Western approach, we can ensure the appropriate management and comfort conditions, regardless of adverse conditions.

It is in this context that we introduce Domotic, a science that is experiencing a growing investment and development.

Currently, the use of home automation systems is presented as a valued and differentiating aspect of a building, although, in most cases, it isn't more than a centralized control for security, lighting, video surveillance, heating, irrigation and multimedia services, without adding anything to the individual management processes of the various systems [5].

Besides that, there is also a strong strand of facilities aimed at the "energy efficiency label" [6].

Depending on the initial investment, on the scale of the building and of the installation, we can find many cases where "energy efficiency" is achieved solely by the resource to certain isolated systems with more efficient features – the result of technical innovations in those processes –, solutions that don't really take advantage of the interaction with the other elements and processes of the dwelling provided by the home automation system.

Thus, the project proposed by us, a Domotic System for the promotion of a Bioclimatic Behavior, intends to establish itself as a truly innovative system, since it addresses the automation and integration of the various equipment, as a whole, to promote the passive operation of the building.

Starting from what constitutes a good Architecture and with the lessons learned from the bioclimatic processes, it is possible, in any building (with more or less efficiency), to establish a passive processes regimen, engaging a thermal behavior in harmony with the environment.

Through these same processes, it is also possible to regulate the various aspects that influence thermal performance, comfort and health factors, creating better living conditions, either by importing, excluding or protecting from certain conditions.

With the proposed system, the management of the housing complex processes and its relation with the internal and external environmental conditions would be easily and efficiently guaranteed, freeing the user of these tasks [7]-[8].

With this, the user would benefit from a building with better conditions than those guaranteed by common standards, with the enormous advantage of enjoying a healthier and more enjoyable atmosphere, with greater relationship with the natural environment, but with lower energy costs [9].

In its management, the system would promote the efficient use of the natural resources, by manipulating the elements at its disposal (louvers, awnings, blinds, heating and cooling equipment, etc.), in order to achieve a common final objective.

In addition to the thermal performance, these systems are upgradeable and easily adaptable to new conditions or elements, fact that makes the building flexible to use in future circumstances.

In fact, more than lighting, HVAC, video, phone and other functions ordinarily associated with these systems, Domotic is a science suited to the future social trends [10].

With a marked population aging rate, today's housing policies in Europe face an increased challenge in the promotion of models and appropriate solutions for this population[11].

In the case of a house equipped with a well-designed domotic system, the building infrastructures would already be in place, easily allowing the introduction and connection of new elements to the system, turning the dwelling appropriate to each person's requirements and disabilities. This may include the addition of special equipment like personal emergency alarms, stair lifters, or the installation of aiding software like a text magnifier, easier communication software, etc.

Being automated systems with simplified controls, the user/house interaction should be easier and more complete.

Besides the evident advantages to the user, the same system and interaction method would also promote the intuitive learning of the local conditions and of the energy efficiency processes, resulting in a generalized increase of the life quality, efficiency and of sustainability,characteristics that would translate to the occupants as to the generalized society alike.

Moreover, this would be a system with huge export potential for its exceptional efficiency in different climates since, being the relationship between the house and the surrounding environment the main premise, the concept and the system would be adaptable to each situation reality and climate conditions.

Lastly, from the public opinion point-of-view, the inclusion of home automation installations is an increasingly desired feature [12].

Therefore, the spread of our proposed system would result, by itself, in the valorization of the building, as of the choice for energy efficiency and sustainability, increasing the user's life quality.

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