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Sustainable buildings with mechanic ventilation and the so-called HVAC strategy: challenges and alternatives

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Abstract

In search for projects for buildings causing less environmental impact, the use of modern building techniques and the decreasing consumption of water and electricity have become important demands to the development of Brazilian market. Construction industry struggles to enhance both its wall, coverage and closing systems and its natural or artificial ventilation strategies able to soften gains and losses of heat between outdoor and indoor areas of buildings. However, despite the availability of appropriate materials to obstruct the passage of heat to buildings due to daily variations of temperature outdoors and to the building envelopment thermal capacity, our construction industry still neglects to make good use of them. Alternatively, provided that appropriate materials are used and, likewise, the local climatic conditions are considered, HVAC strategy supplies considerably better results for thermal comfort in Brazilian sustainable buildings.

Keywords - Sustainability, mechanical ventilation, HVAC and the labor market

1. Introduction

Our first goal in this paper is to review state-of-the-art mechanic ventilation strategies in general and especially HVAC system applied to Brazilian sustainable buildings by presenting discussions on their uses by our construction industry. Called “AVAC” among Brazilians, it is a known fact that HVAC system is a technological strategy responsible for maintaining comfortable internal temperatures of buildings and vehicles by using heating, ventilating and air-conditioning (and occasionally also refrigerating) techniques.

We also have the intention to point out which ways civil engineering, which is ascending our country, should take into account a range of elements simultaneously (for example, those related to comfort, project process,

quality of built areas, technologies for constructing, environmental psychology, computer simulating and post-occupation evaluation of projects). The project and the execution of the edifices have better results if an operating and management apparatus is previously established so that skilled professionals handle the requirements for sustainable buildings.

As technological advance and global changes related to social and economic factors have considerable effects on architectural and civil engineering works (Moraes, 2004; Kowaltowski et al, 2006; and Figueiredo e Silva, 2010), an important agenda was pioneer in creating goals and incentives for sustainable construction in developing countries. The so-called Agenda 21 presented proposals for changing managing practices of housing project elaboration and its execution in order to create new trends in the fields of civil construction to value both natural resources and possibilities of recycling and reusing materials for buildings to become thermally comfortable with less consumption of electric energy.

Construction companies attempt to enhance their services so as to obtain investments despite the fierce competition on the real estate market. Since aesthetic and visual aspects were already explored in innovative projects but energy consumption rates are still high, it has been essential to verify how to soften the sensations of hot and cold that are caused by air-conditioning misuse. In this case, skilled professionals should integrate technical and scientific concepts to their projects to manage acoustic, thermal and functional elements aspects that provide enough comfort for human well-being. Actually, comfort, function and economy should be included in housing projects since the beginning of its elaboration so a group of professionals with multiple knowledge of arts, science and environs psychology can deal with them organically. This is to say that technical labor force operating in the work sites should be previously trained in order to execute the building, mainly because form and function are necessary to avoid failures in buildings. Equally, technical and constructive aspects are vital to make profitable use of wall, coverage and closing systems and ventilation strategies, whether natural or artificial.

It is possible then to enhance thermal performance according to Brazilian local climate, whose peculiarities determine noticeable variations of temperatures during a single day. However, not only climatic conditions but also the characteristics of the materials used during construction interfere in the thermal performance of a building. Consequently, they also interfere both in energy conservation potentials and in the use of air-conditionings indoors.

Factors such as temperature, air humidity and solar radiation play an important role in sustainable solutions with less pollutant emissions and use of renewable resources to retain electricity consumption by air-conditioning systems. Yet Brazilian weather peculiarities are only observed for sustainable edifices responding to LEED certification: contrarily most of our

public buildings and even our graduation courses in the areas of civil engineering and architecture neglect adequate construction procedures for our climate conditions. As a result of the lack of skilled professionals and non-existing control on the part of public administrators, the year of 2015 was characterized by excessive electricity consumption and lack of certain natural resources. Consequently, the price for electricity taxes raised about 50% and in order to save energy the workday in public buildings reduced in 2 hours.

Finally the goals of our paper include to demonstrate the importance of reformulating the processes involved in housing projects of construction industry aiming to develop and evaluate air-conditioning systems (whether they make use of passive or active technologies) so they contribute to the decrease of energy consumption. In other words, this article intends to propose elaborating housing projects based both on the above-mentioned technologies and on Brazilian regions climate, since their peculiarities are decisive for establishing directives relatively to important aspects of the project (for instance, the well-being in residences and the quality of the services done by workers in public buildings).

Chart 1: Proposal for reformulating phases involved in housing projects according to actions to provide thermal comfort. Extracted from Moraes (2008).

Idealization of housing projects	**Phases**	**Air-conditioning systems with less electricity consumption**
	Data research	1. Proposal presented by the owner 2. Climate data 3. Physical and architectural data
Mass study Preliminary studies	Elaborating housing projects according to external and internal features	4. Natural and artificial air-conditioning strategies 5. Defining physical traits of the building
Preliminary draft	Project development	6. Thermal performance evaluation through simulation; 7. Ventilation evaluation through simulation 8. Meeting with members of the construction company, real estate investors and professionals involved for necessary adjustments and project scheduling
Legal project Sales assistance	Computer graphics	9. Thermal performance re-evaluation through simulation (in case of changes in the project);
Pre-executive project Executive project	Detailed project	10. Ventilation re-evaluation through simulation (in case of changes in the project). Adoption of technologies for artificial air-conditioning strategies
Final product		

HVAC system and its uses

Industrially developed in response to a diversified range of demands (from number of users to finality), HVAC system ideally contributes to consumption of less electricity along the processes of construction and use of buildings in general. Its solutions are less harmful to environment as they

make use of renewable resources, causing noticeable decrease of pollutants emission and energy consumption.

According to specialized magazines (Frio, 2013), it is possible to analyze how users of buildings with HVAC ventilation behave through their comfort and productivity (in case of commercial edifices). Both correlation between internal and external temperatures and air velocity and humidity are associated with the sensation of thermal comfort, measured by indexes such as PMV/PPD (Predicted Mean Vote/ Predicted Percentage Dissatisfied) and adaptative comfort, humidity rates and CFD simulation (computational fluid dynamics). According to Fanger (1972), as there will always be those who are not satisfied, even if the conditioning system in their building is ideal, it is not possible there to be full satisfaction with acclimatization. Although HVAC does not have flexibility according to variations in the number of users of a building, the system was praised in buildings where there were independent thermostats for each room. However, specialized workforce is required for its installation and maintenance, as frequently the criticism levelled at HVAC neglects considering the importance of those factors. For instance, once there is not regular maintenance to the equipment, initial setting may change, as the system becomes less efficient, causing dissatisfaction among its users.

Other innovative technologies developed in Brazil

Considering climate conditions of different parts of the country, Brazilian researchers have studied technologies that are currently undergoing testing in order to contribute to reducing electricity and water consumption. Brazilian multinational WEG S.A., for instance, created "WEG solution", a sustainable alternative for cooling towers. Once associated with W22 Premium motor and variable-speed drive CFW701 HVAC, the amounts of total saved energy vary from 40% to 80% (48% of them being related to electricity itself and 22% corresponding to reductions in water consumption). Moreover, the company also produces a device for showers named Ecoshower, contributing not only to extending the service life of the appliance but also to saving water and electric energy.

Sustainable tendencies

It is noticeable that searching for cheaper electricity taxes and, at the same time, thermal comfort, users of buildings in general attempt to find technologies supplying eco-friendly materials for constructions. Taps with movement sensor and dual-flushed water toilet bowls cause considerable reduction of water consumption. Similarly, LED lights are used to save electricity, besides having a longer service life and avoiding overheating in the rooms where they are installed. Moreover, there are plenty of other materials appropriate for sustainable constructions, such as

- Finishing material (water-based glues and paints, being varnish, waterproofing and solvent made of vegetable oils);

- Wall-building materials (cement, sand, water and crushed stone components give rise to recyclable concrete), and
- certified timber

In this regard it is equally important to remark noticeable trends in civil construction sector aiming to assess buildings sustainability through certificates and seals of approval, such as LEED. With worldwide acceptance, LEED purpose is to raise technical standards throughout construction market by providing concepts for products and sustainable technologies. Intended to promote industrialization relatively to buildings and to abate informalities in construction market, LEED certification is granted for companies whose buildings conform to GBC norms. In return, real estate investors of companies such as Unilever, Eldorado Business Tower (São Paulo) and Coca-Cola factory in Rio Grande farm (Paraná) have political and fiscal facilities.

Construction professionals may also count on "Procel Edificações", a Brazilian seal of energy efficiency delivered to edifices satisfying high performances for electricity efficacy (AAA label) according to three categories (lighting, envelopment and HVAC). In addition, law projects support national policies for making rational use of energy. By way of illustration, São Paulo legislative chamber has analyzed mayor Fernando Haddad's law project which previews deducting 12% from property taxes of edifices that demonstrably adopt measures to reduce impacts on the environment.

HVAC-R Marketing overview according to Abrava surveys

Important researches carried out by Economy and Statistics Department of Brazilian association for matters of refrigeration, air-conditioning, ventilation and heating (Forato, 2015), HVAC marketing indexes have been raising for seven years. For instance, comparatively to 2008, HVAC sales tax during 2015 increased 43% on average.

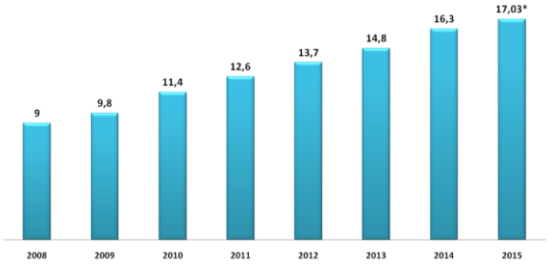

Figure 1. HVAC-R in Brazilian market. Sales in US$ billions from 2008 to 2015

Nonetheless, customers still resist buying HVAC-R equipment due to its high cost and spent electricity rates. Abrava surveys carried out along 2014 could identify the most important aspects for customers to acquiring residential air-conditioning systems:

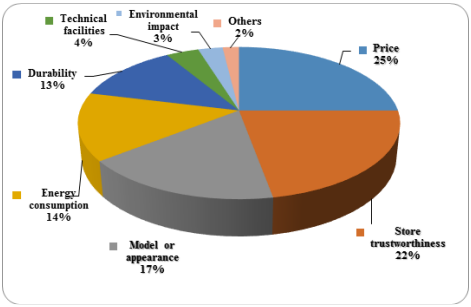

Figure 2. Survey carried out by Abrava Economy and Statistics Department in 2014

Furthermore, Abrava also drafted an overview on the sales of varied air-conditioning systems once taken into consideration each Brazilian region (pictures from 3 to 6 below) with its population density (picture 7). Thus, the association could analyze a market research of air-conditioning systems broadly speaking (pictures from 8 to 15 to follow).

Figure 3. Air conditioning market for Splits by regions 2015.

Figure 4. Air Conditioning Market for Fan Coil by regions

Figure 5. Air Conditioning Market for Chiller (A.G.) by regions.

Figure 6. Air Conditioning Market for Self-Contained by regions.

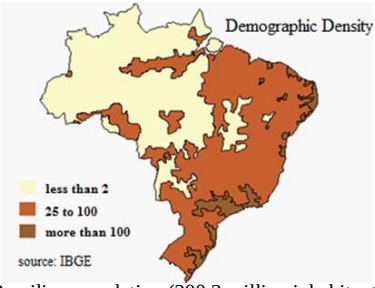

Figure 7. Brazilian population (200.2 million inhabitants) in 2014.

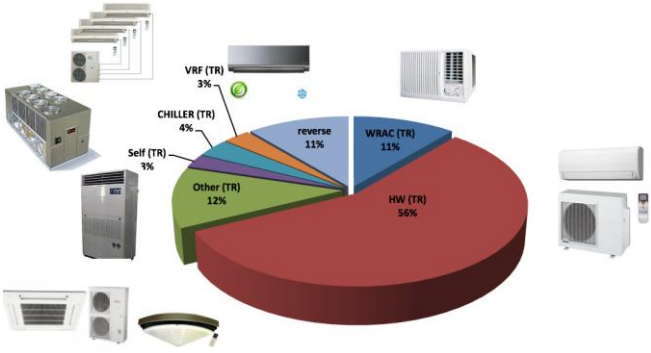

Figure 8. Market residential air-conditioners - 2015*
* = Projection

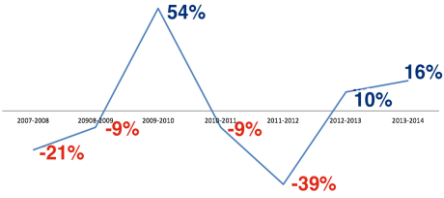

Figure 9. Market development: WRAC (window apparatus).

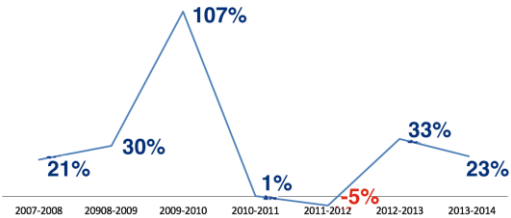

Figure 10. Market development: HW (Splits).

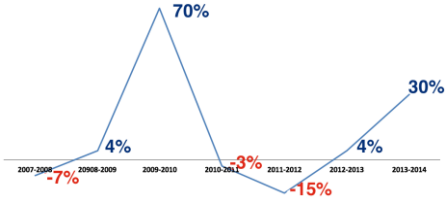

Figure 11. Market development: Others (floor-ceiling ducts, etc.)

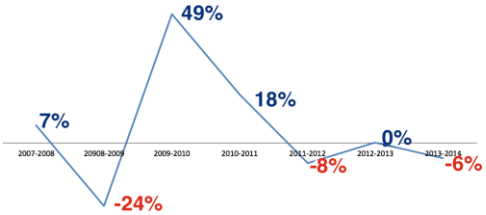

Figure 12. Market development for self-contained.

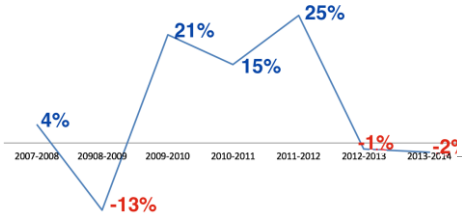

Figure 13. Market development of chillers

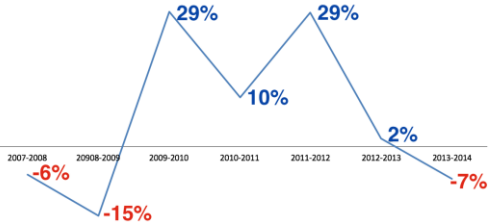

Figure 14. Market development of fan coils

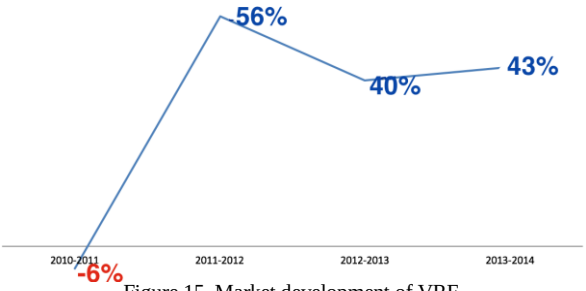

Figure 15. Market development of VRF.

2. Results and discussions

Analyzing both the development and the employed strategies in construction market (by the way, one the largest foundations of Brazilian gross domestic product), it is reasonable to assume the ultimate importance of reviewing housing projects stages and actions for the benefit of their execution and thermal comfort assessment. It is possible then to obtain agility and precision as requirements for elaborating projects and constructing, which can determine whether real estate investments achieve the desired results or not. In other words, once routine actions are aligned with strategic goals, they can give rise to solid and lucrative business (Alves, Costa and Barros Neto, 2009).

Knowing behavioral factors involved in the process of elaborating projects remains a challenge, given that humanist and scientific concepts are appropriate not only to improve buildings quality but also to create identity among the project, its execution and users. In order to guarantee the users are comfortable relatively to the building thermal conditions, bearing in mind daily variations of external temperature in the locality and the thermal capacity of the edifice envelopment is crucial. Being characterized by sharp variations of temperature along a single day, certain Brazilian regions demand people habits and housing projects adapt to their climate conditions,

so that gains and losses of heating from external to internal areas of the building are softened. Contrarily, neglecting considering those factors may lead edifices users to certain diseases (implying justifiable reasons for anticipated or unexpected retirement, in case the building belongs to Brazilian public administration, for instance)1.

Ventilation expansion in sustainable housing projects and HVAC system increasing use in them have proven that since the initial stages of the elaboration of them cooling concepts of buildings with air-conditioning equipment should be present (as in chart 1 above). Likewise, multidisciplinary teams meeting the needs of projects jointly and taking bolder actions in the benefit of the environment (by using evaluation and certification systems, for instance) are equally helpful to contain the problems emerged from energy crisis in Brazil through 2015.

3. Final remarks

Once inserted in the production cycle of civil construction industry, housing projects have proven to be a valuable tool in attempt to lower costs of production, reach the desired quality. Furthermore, those projects may reduce the occurrence of mistakes involving decision-making process technologically based aiming to rationalize their execution.

Since projects are one of the first stages of buildings production process, they play an essential role both on their overall costs and on their quality. Similarly, assessing the environmental quality of a building leads to broader perspectives on the technical requirements for constructions according to the customers' needs, the local climate conditions and the architectural party adopted (shade, full sun, building implantation on lots, etc.). As air-conditioning systems conform growing markets, the use of HVAC system provides the building with thermal comfort and ensures post-occupation reforms and restorations for cooling the edifice are expendable.

To sum up, if all the issues involved in constructions are part of a single one, possible solutions should be organically conformed, since different criteria used to solve them enable profitable effects:

- fast technological development,
- different perceptions and demands on the part of the owners of the buildings;
- building importance increases, facilitating productivity
- development of databases in line with computer graphics (CAD e BIM), providing the professionals in charge of the project with

[1] As differences in temperatures are felt while a user enters or leaves a building, a recent survey pointed out that Brazilian university students usually opt for air-conditioning quite low temperatures as they enter their classroom after lunchtime so as to avoid falling asleep during their lessons. When the habit becomes frequent, there is some risk of heart diseases, for instance (Moraes, 2009).

online assessment of chosen variables, which enables interactivity for decision-making

- enhancements for information exchange and human control, enabling sustainable constructions based on low-energy passive building.

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