Examining the Environmental and Energy Challenges of Slums in São Paulo, Brazil

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ABSTRACT

*The city of São Paulo is the richest city in Brazil, accounting for more than 12% of the national GDP, offering employment opportunities for the countries' middle class as well as for the poor (*IBGE, 2012*). As a result, approximate 2 million people live in slums with deficient urban infrastructure (*FRANÇA, COSTA, 2012*). In the last decade, the increase buying power of the low income families in the big cities of the country has caused a dramatic raise on electricity demand due to the acquisition of domestic appliances, which have proved to become comparable to those of middle class, based on the data gathering in the fieldwork research presented in this paper. Hence, the growth of urban slums in Sao Paulo is associated with the increase of its population density accompanied by an increase of electricity demand, adding pressure on the precarious infrastructure and impoverishing even more the living conditions, due to the accumulation of heat gains in compact irregular and overcrowded housing, agglomerated in informal settlements of poor quality open spaces. In this context, this work examines the environmental challenges of slums in the city of São Paulo, the so called "favelas", drawing from two cases: "favela Morro da USP", covering 18.500m² and housing 515 families, and "favela Paraisopolis", the second biggest in São Paulo, with almost 60.000 inhabitants living over 100 hectares. Field work has shown energy consumption of the slums' households of around 220kwh/month, the equivalent to the typical figures from the local middle class homes. In addition, the environmental research has identified the potencial of improving internal conditions with bigger openings to higher ventilation rates and shading of roof components.*

INTRODUCTION

Being the 10th richest city in the world, São Paulo entered the new century accounting for 12.26% of the national GDP and 36% of the total output of goods and services of the State of São Paulo (IBGE, 2012). Associated with its economic development, the city of São Paulo is seen as a place of employment opportunities, availability of infrastructure and assess to education, health, leisure and culture in the country. On the other hand, economic and urban growth has also reflected in a series of socio-economic, urban and environmental negative impacts, compromising the quality of life of various neighbourhoods in the city, formal and informal. In this context, the housing deficit is one of the most critical issues in the city. According to the census of 2010 (IBGE, 2010), 1.16 million people were counted

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in the slums, 1.8 million inhabitants in irregular settlements, and about 9,000 homeless in the city of São Paulo. The phenomena of the *favelas* in São Paulo, which started in the 70s, became visible and distinguished in the urban fabric of the city (figure 1).

Covering an area of almost 2 hectares (18.500m²) and housing 515 families, *Favela Morro da USP* is a small informal settlement where 50% of residents live in units smaller than $30m^2$ (Pizarro, 2014). On the other end, *Favela Paraisopolis* is the second biggest slum in São Paulo, with almost 60.000 inhabitants living over 100 hectares (França, Costa, 2012). Whilst the first case has the population and a total area equivalent to a couple of typical urban blocks, *Paraisopolis* covers a territory of a medium size city in the country. Despite these differences, both case studies have similar social and physical structure, typical of the consolidated urban slums in the city. The consolidated slum in São Paulo has a basic infrastructure in place (roads, water, sewage and energy utilities), the permanent character of the buildings and the identification of a coherent social organization. Problems for the quality of life are found in the lack of open spaces and in the environmental conditions of the residences.

Figure 1 Overview of *Paraisopolis*, the 2nd biggest slum of Sao Paulo, in cityscape of the city. Photo: Eduardo Pizarro.

CLIMATE

The city of São Paulo is located in the latitude 23º24'south, with a tropical climate subjected to the effects of altitude (approximately 800 metres above sea level) where thermal comfort is likely to be achieved for approximately 70% of the year (ASHRAE, 2009). The climate offers sunny winter days, when direct solar radiation is a key factor for thermal comfort, especially in outdoor spaces, and partially cloudy days in summer, when the main strategy for thermal comfort is solar protection combined with natural ventilation.The mean air temperature in the summer months stays around 23°C, whilst humidity can easily reach 80 per cent (figure 2). However, it is worth highlighting that in the hot periods of the year, thermal comfort indoors and outdoors is highly dependent on shading strategies and proper ventilation rates. Winters are mild, with mean air temperatures between 16°C and 18°C, though even in winter relative humidity stays high. Heating demand is identified for short periods of the year, being easily solved passively with solar gains and internal gains from dense ocuppantion patterns.

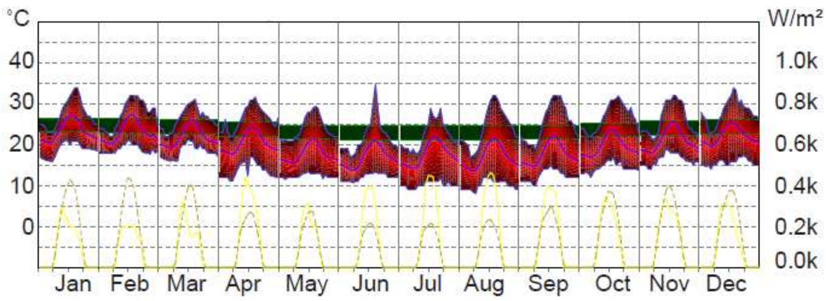


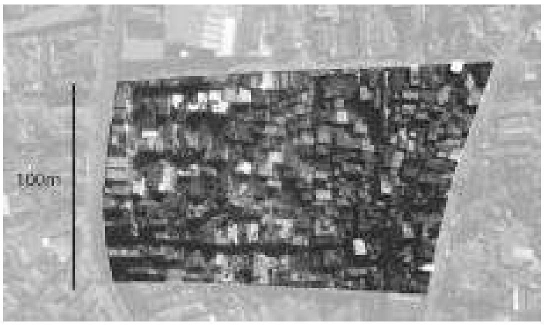
Figure 2 Monthly average temperatures of the climate of Sao Paulo with incident radiation. Source: Pizarro, 2014.

In addition to the characteristics of the natural climate, the city presents a huge variety of urban microclimates, influenced by the multiple aspects of the urban form and human activities and characterized by problems with air quality, urban heat islands, poor urban ventilation, urban noise, among others, which affect the quality of both open spaces and buildings, typical in the slums (CETESB, 1990, Silva, Ribeiro, 2006). Moreover, it is important to consider that, in the residential units, high occupation density coupled with insufficient air changes (due to small windows), compromise the internal environmental conditions in the warm days of the year, as shown bellow.

THE BUILT ENVIRONMENT OF SLUMS

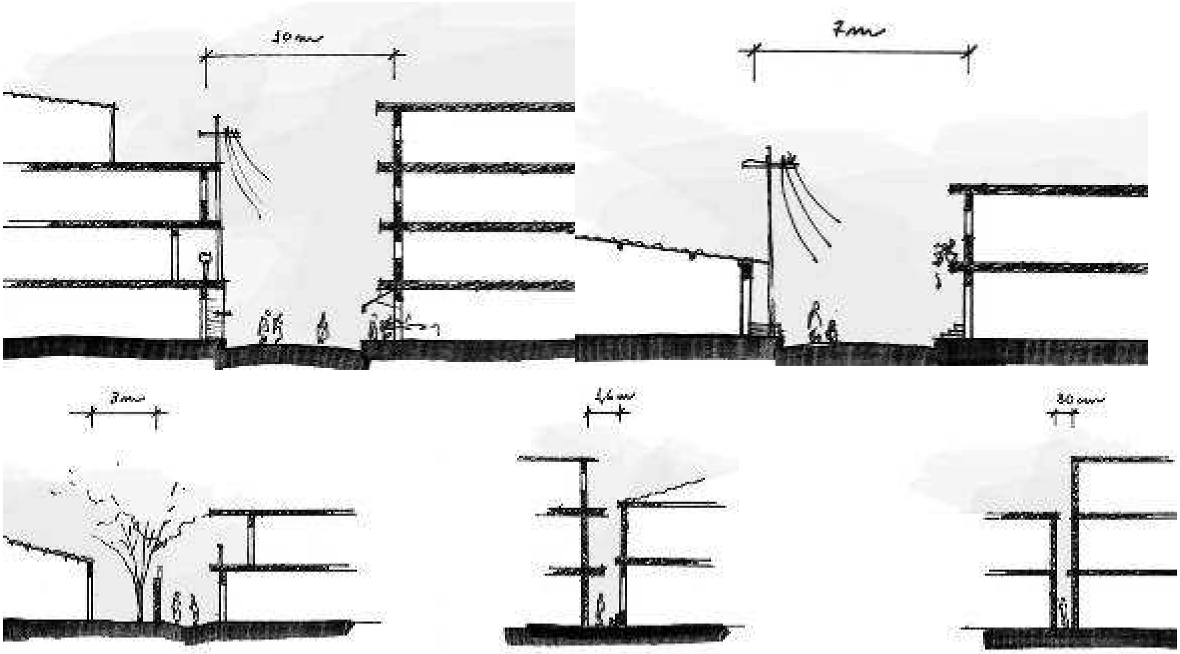
Urban fabric

Originally, the urban fabric of both case studies (as in the majority of slums in Sao Paulo) developed on top of a formal parceling of the territory (figures 3 and 4). As a consequence, main roads were kept within their original size (10 meters long), whilst a complex grid of alleys grew within the urban blocks to give access by foot to the internal and smaller residential units (figures 5 to 8). As a result, the built environment is characterized by a diveristy of circulation spaces with constrasting environmental conditions in need of improvement. The compactness of the urban blocks leads to lack of vegetation and space to the accommodation of urban and living activities, which are either castigated by solar radiation or deprived of daylight and air flow between buildings due to the rather narrow canyons (figures 5 and 6).



Figures 3 and 4 On the left, the urban fabric of *Favela Paraisopolis*, over 100 hectares. On the right, the site planning of *Favela Morro da USP*, covering the small area of 2 hectares. Despite the difference in size, both cases have a similar parttern of urban fabric. Source: Pizarro, 2014.

Figures 5 and 6 The urban environment in *Favela Paraisopolis*. On the left, the canyon and socioeconomic activities on the pavement of the main street. On the right, the appropriation of open space of the alley. Photo: Eduardo Pizarro.



Figures 7 and 8 Sections of the typical canyons in the slums of *Morro da USP* and *Paraisópolis*. Above two of the main streets shared by pedestrians and cars. Below the pedestrians´ alley. Source: Pizarro, 2014.

The building

The buildings in the slums of Sao Paulo vary from one to four storeys, supported by concrete columns and beams and brick walls. The area of the residential unit (one per floor), vary from 30 to 50m^2, for an average family size of four people. Typically, each residence has one façade to the exterior. As identified in Samora and Vosgueritchian (2006), the limited exposure to the outside combined with the compatness of the urban fabric incurs to internal spaces characterized by lack of solar access, daylight and ventilation. On the other hand, the thermal capacity of the buildings, in addition to the self shading of the urban fabric and external shading strategies, protects internal and external spaces from the harsh impact of solar radiation.

Figures 9 and 10 On the left, view of a typical street within the fabric of *Favela Morro da USP*. On the right, view of multistorey buildings supported by concrete columns and beams with brick walls.

ENVIRONMENTAL CONDITIONS AND CHALLENGES

Outdoor environment: walking through the streets of *Paraisopolis*

Measuraments of environmental variables in the streets of *Paraisopolis* included air temperatures, surface temperatures, relative humidity and air movement. Comparing the results found in the streets with those from the alleys, the fieldwork showed the significant positive impact of the shading and shaded mass in reducing surface and air temperatures in hot days. The unshaded street presented surface temperatures as high as 50°C and air temperature around 36°C (figure 11). In contrast to that, within a short period of time, the protected space of alley had higher air temperatures around 36 °C but significantly lower surface temperatures, showing figures around 28 °C, which have a major favourable impact on pedestrians' comfort and on the thermal conditions within the rooms facing the alleys (figure 12). Air movement also varied from higher than 2 m/s in the main street to around 1.5 m/s in the alley, in the best scenario. Nevertheless, insufficient daylighting in the alleys is obvious.

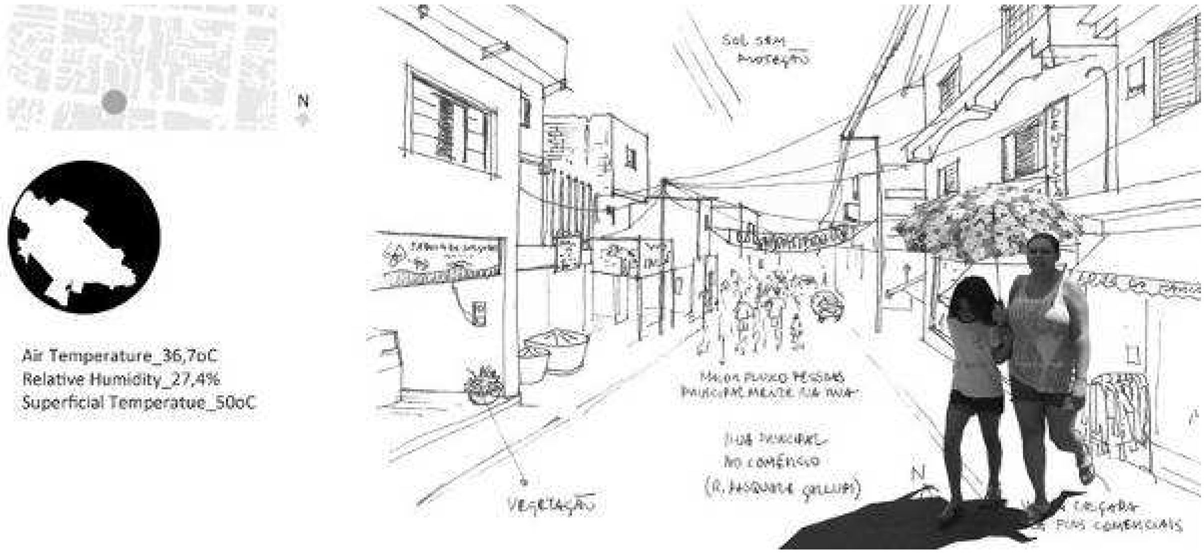


Figure 11 Sinthesis of thermal conditions in one of the main streets of *Paraisopolis,* showing air temperature, surface temperature, relative humidty and air movement taken on a hot day at 4 pm. Source: Pizarro, 2014.

Figure 12 Sinthesis of external thermal conditions in one alley, showing air temperature, surface temperature, relative humidty and air movement on a hot summer day at 4:15 pm. Source: Pizarro, 2014.

Thermal environment in internal spaces

Measuraments of thermal conditions of an internal space were taken in one of the houses facing a main street. The exposure to solar radiation coupled with the concentration of internal gains and insufficient ventilation rates resulted in air temperatures as high as 40°C in the living space (bringing together living and kitchen in one area) at 4 pm of a week day, when outdoor temperatures oscilated around 33 °C (figure 13). The way windows are design, protection against solar gains would inevitably block the already limited air ventilation rates, so as a common practice, windows are kept open by the occupants during the day in order to provide some air movement, however, inefficient to control the rise of internal temperatures. At nitgh, internal temperatures drop up to 10 ^oC. It is known that windows are kept open during the night allowing for nitgh time cooling of the internal spaces and the building fabric of brick walls and concrete block ceilings. However, during the internal temperatures quickly go up to 35^{o}C and than 40^{o}C degrees during the 1st half of the day. In principle, solar protection and higher ventilation rates would improve such conditions.

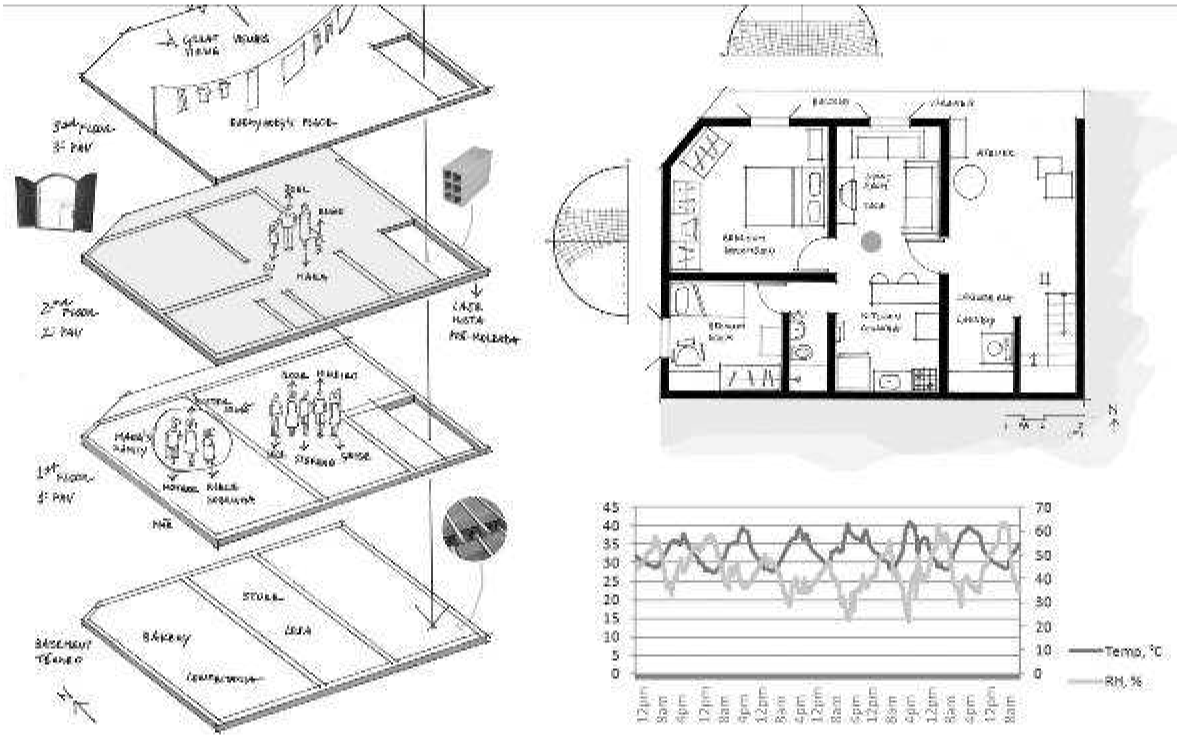


Figure 13 Measuraments of air temperature in a residencial unit with a multistory building, facing a main street in *Paraisopolis*. Source: Pizarro, 2014.

ENERGY DEMAND: THE CASE STUDY OF *FAVELA MORRO DA USP*

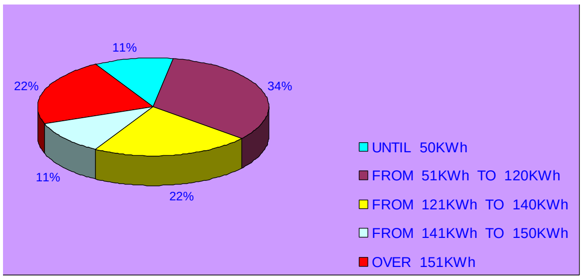
The main type of energy consumed in the building sector in Brazil is electrical. The electricity consumption in the Brazilian residential sector represented 20% of the total in 1991, whilst in 2000 it grew to 27% (CCPE, 2004). In the group of cities of the South-East region of the country, where São Paulo is located, the main energy consumer is the fridge with approximately 30%, followed by the electric shower with approximately 26% and the artificial lighting with approximately 10% (Guisi *at al*, 2007). Looking at the electricity consumption in a typical middle class residence in São Paulo, this trend results in a average of 117Kwh/ m^2 month, in a residence of around 70m^2 (BESP, 2009). Compared with data from the National Energy Balance (BEN, 2010), the numbers relating to residential energy consumption in São Paulo are very close to the national average, being 113kWh/m^2. It is worth noticing that almost 40% of the residential energy consumption range from 100 to 160kWh/m2, with an average of 3.2 people per family (BEN, 2010).

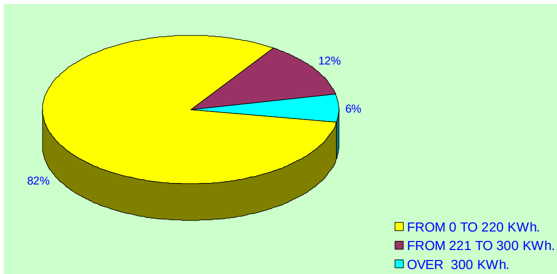
Looking at the case of *Favela Morro da USP*, although almost 70% of its population have an monthly income below five minimum wages (between U$545,00 and U$1.818,00), proving the hypothesis that the consumption of electricity in consolidated favelas has a similar pattern to that from the local middle class homes in Brazil (Pizarro, 2014). This is due to the increasing acccess to affordable appliances. As the enegy demand grows in consolidated slums, as in *Morro da USP*, the provision of electricity becomes problematic for two reasons: the difficult access to the residential units, due to the informal use of land and compact nature of the built envionemnt, and the dynamic changes of the slums' social and physical structures. The precarious nature of living combined with great expansion of self-built units and subdivisions of one residence in multiple ones (figures 14 e 15), imposes a fundamental challenge to the task of checking and monitoring the consumption of the different buildings and families.

In *Favela Morro da USP* it is common to observe a single residencial unit housing two or more families, which would demand different electricity meters. In a number of cases, the informal sharing of the spaces and domestic appliances between families makes the division in electricity consumption of different families not clearly distinguishable and difficult to be priced.


Figures 14 e 15 On the left, the precarious electricity grid running in front of windows in favela *Morro da USP*.On the right, the multiple electricity meters installed in one residential building.

In this context, the total monthly energy consumption by household cannot be translated into kWh/m^2, once the area occupied by each household is a constant changing factor and cannot be simply identified by the plot ratio of the building. In order to present a clear energy consumption profile, the figures chosen to illustrate the electricity consumption in the case study of Favela *Morro de São Paulo* refer to only one month, corresponding to the biggest number of households being registered in the year of the fieldwork, May 2013 (Pizarro, 2014). The fieldwork showed that for 82% of households the threshold of electricity consumption is 200kwh per month, thus achieving the Social Discount Rate Low Income, created by the Federal Government in January 2010 (figure 16 e 17). The new social tariff of electricity consumption promoted discounts for social housing, varying between 10% a 65% in cases which the monthly family income per capita is equal or less than half of the national minimum wage. The degree of discount is associated with the household consumption, varying from the minimum of 30kWh per month for the maximum discount of 65%, to 202kWh per month for the minimum discount of 10%.





Figures 16 e 17 Energy consumption in the residential buildings of Favela *Morro da USP* in May 2013. On the left, the percentage of households below 50kWh and above, including demands over 151kWh. On the right, a detail assessment of consumption above 1501kWh, with 82% up to 220kWh, the threshold of the Social Discount Rate Low Income, and percentage of units above.

With respects to life-style, it is important to note that the population of consolidated favelas such as Morro de São Paulo, where addresses have been established based on to energy and sewage bills, has led residents to have access to bank credit and, therefore, to domestic appliances existing in a typical middle-class residence in Brazil (TV, microwaves, stereos, computers, irons, electric shower, washing machine, etc.). The gradual increase in the buying power of the low income sector in Brazil, which is visible and practiced in the city of Sao Paulo is among the factors that justify the levels of energy consumption shown in figures 16 and 17. In order words, the oficialization of energy consumption has become an efficient way of socioeconomic inclusion. Nevertheless, the challenges to access all residential units, provide electricity with a safe grid and measure the consumption of individual households remain. Furthermore, the compact urban fabric of the favela results in a highly-concentrated energy demand. In this scenario, to avoid risks of power supply for electricity, implementation of conventional infrastructure facilities could be planned with the introduction of the so called alternative or ”green” technologies, such as solar collectors for water heating and photovoltaic cells for electriccity.

FINAL CONSIDERATIONS

Access to electricity became an effective means of social inclusion. In that sense, since the energy bill is associated with a formal address, within an informal urban settlement, the households have the minimum requirements to take part in the formalozed market of goods and appliances, including the access to financial credits. In addition to that, contrary to the misconception that low income families inherit inefficient domestic appliances (or have none at all), the reality in consolidated *favelas* is that there is a trend of energy consumption similar to those of the overall residential sector in the region. On the other hand, different from the formal part of the residential sector, the energy supply in *favelas* faces the challenges brought by the constant growth and changing of the physical environment, including the horizontal and vertical expansion and multiple subdivisions of one building in several households.

From the point of view of broader environmental issues, whilst energy consumption shows the increasing buying power of low income families living in *favelas* in São Paulo, the comfort of the inhabitants inside the buildings and the environmental conditions of open public spaces do not offer good quality. In this respect, the performance of the local built environment of the *favela* with the principles of environmental design for the specific climate of São Paulo needs to be further improved both for indoor and outdoor spaces, if quality of life is to be provided beyond access to energy.

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