Analysis of sustainability in the Brazilian housing production: The case of AP4 - Rio de Janeiro

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ABSTRACT: The study presents a brief analysis of the sustainability conditions related to housing production in Brazil having as study area the region of the West Zone of Rio de Janeiro City administratively known as Planning Area 4 - AP4, where the neighborhoods of greatest population growth in the first decade of this century are situated. For the analysis in question social, economic, energy and environmental indicators were established, which identified disparate socioeconomic results in the region as opposed to the exponential growth of the real estate market intended for middle and high income classes in the region. The result points to the urgent transformation in the construction industry mode of production in Brazil and aims at achieving greater energy and environmental efficiency with positive impacts on the socioeconomic factors.

Keyword *Sustainability , housing, energy efficiency.*

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1. INTRODUCTION

The City of Rio de Janeiro concentrates a population of approximately 6.4 million people, of which 1.4 million people live in 763 slums in Rio, i.e. over 20% of city dwellers live in slums according to IBGE data - Brazilian Institute of Geography and Statistics. Much of this population living in slums live in subnormal situation without access to urban infrastructure, mobility, health and safety, and a significant portion is located in the Planning Area 4 - AP4 in the metropolitan area of the city of Rio de Janeiro, which will be the focus of the study carried out.

The AP4 region is one that suffers greatest pressure from the housing market for the expansion of housing supply and commercial centers boasting a population growth of around 70% in the last decade. Moreover, the construction environment in that region is represented by the traditional building industry, characterized by low innovation and by repetition techniques as well as high-energy consumption and low environmental quality materials, contrary to the triad of sustainability which calls for environmental, social and economic balance.

In this scenario the focus in question analyzes the concept of human environment - scenario of social relations and the main stage of the interventions resulting from its transformation, where the Construction Industry plays a major role in the reproduction of the built environment featuring strong contribution both in energy consumption and the equivalent CO_2 emissions, and on the other hand, accentuating the strong social inequality and the meager access to quality urban infrastructure resulting from urban sprawl.

To achieve the proposed analysis we established socioeconomic and energy-environmental indicators represented respectively by demographic profile, subnormal occupations and Social Development Index (SDI) of the study area, and by the energy intensity and CO_2 equivalent emissions in the residential construction sector in order to evaluate the urban development and environmental conditions of the region according to global sustainability criteria.

2. PROBLEM BACKGROUND

2.1 Brazilian housing scenario

The global population growth has been boosted exponentially in the last century indicating a population of about ten billion people by 2050, with more than 80% of this quota living in cities. Brazil, following the global trend, should provide ways to promote housing for about 170 million people living in cities, which added to the current housing deficit, may represent about ten million urban households in 2050 resulting in the further exploitation of present limited environmental resources, that is currently leading to a shortage. Figure 1 shows the resident population in Brazil from 1900 to 2010 (Census) and 2020-2100 projections.

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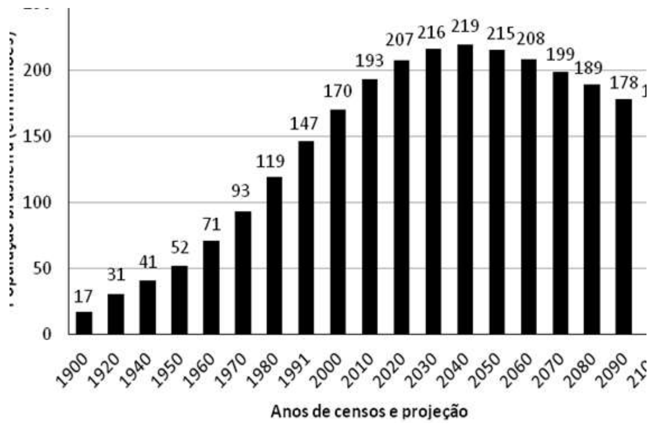

Figure 1. Brazilian population and population projections: 1900-2100 . (Source : IBGE . In: Alves s / d)

On the other hand, urban policies in Brazil support the National Housing Policy - PNH, especially through the Federal Law No. 10.257 / 2001, known as the City Statute, which establishes general guidelines on the Brazilian urban policy. According to this instrument the full development of the social functions of the city and of urban property is highlighted and sustainability (environmental, social and economic) stands out with a view to adopting production guidelines and consumption patterns of goods and services and urban expansion compatible with the limits of environmental, social and economic sustainability of the municipality and the territory under its area of influence (Brazil 2001).

Specifically in relation to sustainability, the PNH actions refer to the Brazilian Program of Quality and Productivity of Habitat (PBQP-H), which despite involving quality improvement actions of products and services through company certification, opposing technical non-compliance in the use of building materials and stimulating the production of more sustainable materials and innovative construction systems, do not represent a systematic change in the construction industry to indicate a significant reduction in the use of environmental resources, especially energy, which is still inconsistent in meeting socioeconomic and environmental requirements as they cannot reduce the strong anomaly related to substandard settlements and lack of adequate infrastructure and urban mobility.

In reference to the subnormal agglomerates comprising a wide diversity of irregular settlements in Brazil known as favelas, invasions, grottoes, lowlands, communities, villages, undertow areas, hovels, stilt houses, among others (Ibge 2010), it is important to highlight that the more developed regions of the country, such as the cities of Rio de Janeiro and Sao Paulo, are those with the highest percentage of occurrence as shown in Figure 2. This indicates a distortion in the application of resources affecting the social development and consequently having negative impacts on the environment.

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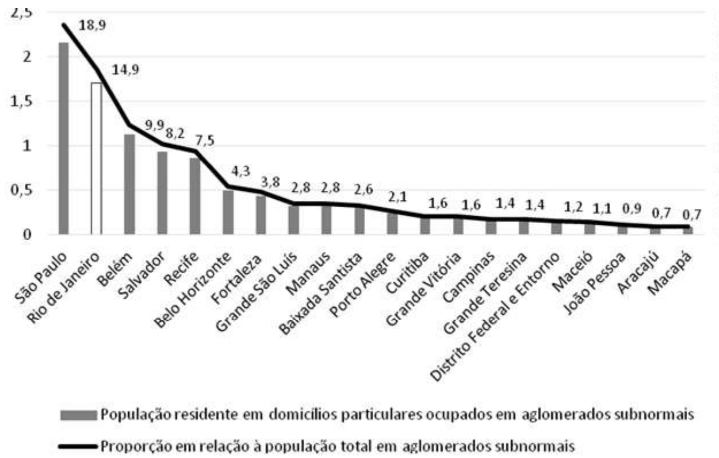

Figure 2. Population distribution in subnormal agglomerates, and the total proportion to the total population in subnormal settlements , according to the metropolitan areas - 2010 (Source : IBGE 2010) .

2.2. Selected Indicators

The indicators selected for analysis of sustainability in housing production of Planning Area 4 located in the region of the West Zone of Rio de Janeiro City were: (1) socioeconomic: (a) resident population, according to census and overall figures; (b) area occupied by slums; and (c) SDI (Social Development Index). These indicators permit, among others, the analysis of the form of growth in the study area; and (2) energy and environmental: (a) energy - represented by the energy content of construction inputs (tEP / m2); and (b) environmental - represented by emissions of CO2 (tCO2 / m2). The Analysis Tool for Energy and Environmental Sustainability in Buildings, the parameter of these two indicators, aims to assess the energy consumption of building materials (Cruz et al. 2004).

2.3 Methodology

Aiming at the development of the analysis according to the indicators presented in Section 2.2 the main elements involved in the production of the built environment were initially identified: socio-spatial organization (item 1) and materials used in construction (item 2).

Item 1, which refers to socioeconomics, considers the socio-spatial organization of both the architectural object individually and the built environment, and includes the social, economic and development characteristics of the studied region. In order to obtain the results, census data from IBGE between the years 2000 and 2010 as well as socioeconomic information on the AP4 obtained from the Pereira Passos Institute (IPP, 2015) were used. Data were analyzed according to the allocation of public funds versus the situation of informality and access to urban infrastructure.

Item 2, concerning energy and environment, refers to the use of construction materials as the main consumption factor in the construction industry, the most used materials and higher energy content for the production of cement, red ceramics, steel and aggregates .

The figures used for the calculation of energy indicators were taken from the National Energy Balance (EPE, 2010) and included the energy inputs for the production process of each material. As for the calculation of environmental indicators IPCC (Intergovernmental Panel on Climate Change, 2010) carbon emissions indexes were considered.

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The calculations were made from the identification of each energy source used in the production sub-sector of the material, and accounting of consumption for each ton of the produced material in 2010. From the result of energy consumption per input, the corresponding emission of CO2eq according to data provided by the IPCC in 2010 was calculated. The results allow us to observe the total energy consumption and emissions of CO2e per ton of material, and therefore, per square meter (m2) built with a view to standard conventional construction.

3. THE AP4 CASE

3.1. Housing production in AP4

Rio de Janeiro City has five planning areas characterized by location, physical, social and economic characteristics. Most of the infrastructure services and public assets are located in the Planning Areas 1 and 2 (AP1 Center and AP2 South Zone) occupied formally by the most privileged social classes and the headquarters of large corporations, and also informally by subnormal occupations and slums, as can be seen in Figure 3.

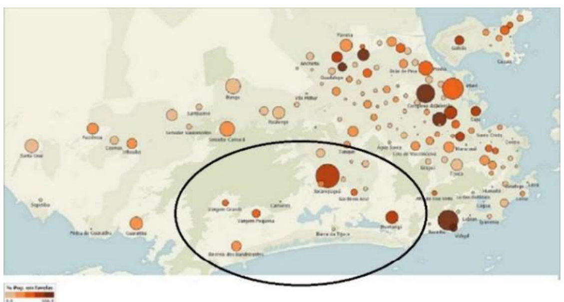

Figure 3. Subnormal occupations and slums at AP4 (Source: Modified LPP 2015b).

In Rio de Janeiro City the majority of the population with income ranging between 0 and 3 minimum wages is concentrated in neighborhoods located in the north and west of the city such as Jacarepagua and Vargem Grande, both located in AP4. According to data presented by Plácido & Ambrosio (2013) the AP4 registered a growth of 72.7 per cent in the 20 years between 1991 and 2010, consolidating the region as the most representative to the housing growth in Rio de Janeiro. To get an idea of the importance of the city of Rio de Janeiro and Planning Area 4, respectively, it is estimated that in 2020, the resident population will be, respectively, 6,661,359 inhabitants and 1,077,930 inhabitants (IPP 2015a).

Figure 4. Population in Rio de Janeiro City. (Source: Placido & Ambrósio 2013).

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Figure 4 shows the density per district in the city of Rio de Janeiro (darker areas with higher density) indicating that the AP4 region is among the most populated with over 100,000 inhabitants. To meet this growth all the housing production in the last decades in AP4 was based mostly on the traditional field of construction, which can be translated into the use of traditional materials such as ceramic and / or concrete sealing blocks and reinforced concrete structures. In Brazil the construction industry shows low modernization initiatives, perpetuating the use of materials and techniques in intensive energy use (Table 5) and, consequently, large emitters of C02. This mindset of low flexibility and high concentration of energy is characteristic of traditional building of low sustainability.

As shown in Table 1 in 2014 occupancy permit was obtained for 1,012,994m2 intended for residential use in the Planning Area 4, which is an energy intensity over 28,000 toe for housing construction. In the year 2010 the energy intensity of construction in AP4 reached figures close to 40,000 toe. That is, the energy present in residential construction in AP4 in 2010 was equivalent to 169,235.89MWh, which would be enough to supply a city of 400,000 inhabitants for one year.

Table 1. Housing production and overall energy intensity between 2010 and 2014 - Planning Area 4.

AP4 - Rio de Janeiro	toe/m2	2010	2014
Area (m2)		1,332,197	1,012,994
Energy Intensity (tEP)	0.0279477398	37,231.90	28,310.89

Source: Adapted from Cruz et al. 2004.

3.2 Socioeconomic evaluation

The growth of the resident population of AP4 in recent decades can be seen in Table 2. In 1991, it represented 9.6% of the municipality, and in 2000 it came to represent 15.4%. Within the Planning Area 4, Barra da Tijuca, for example, had a substantial growth from 1960 (2,580) to 2000 (174,353), equivalent to an increase of 6,657.87%, much higher than that of Rio de Janeiro in the same period, which was 77.13% (Silva, 2006). In this analysis, it should be noted that in Rio de Janeiro there was a population growth of 63.6% in slums (subnormal sector) and only 6.05% in the normal census tract. These values are higher if one considers the Planning Area 4 (228.11% and 48.23%, respectively). That is, as the formal areas grow in the municipality of Rio de Janeiro, the informal areas grow even more, and with this uncontrolled growth, problems related to unplanned growth, such as lack of infrastructure (sewerage, electricity, transport, etc.) increase.

Table 2. Resident population in Rio de Janeiro and Planning Area 4, by sector and total.

Subnormal			
Brazil, City (RJ) and AP4	Resident Population		
	1991	2000	2010
Brazil	4,478,177	6,535,634	11,425,644
Rio de Janeiro	882,483	1,092,783	1,443,773
AP 4	72,182	144,298	236,834
Normal			
Brazil, City (RJ) and AP4	Resident Population		
	1991	2000	2010
Brazil	142,347,298	163,263,536	178,648,144

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Rio de Janeiro	4,598,295	4,759,131	4,876,673
AP 4	454,120	573,729	673,121
Total			
	Resident Population		
Brazil, City (RJ) and AP4	1991	2000	2010
Brazil	146,825,475	169,799,170	190,073,788
Rio de Janeiro	5,480,768	5,857,904	6,320,446
AP 4	526,302	682,051	909,955

Source: Modified IPP by Census IBGE.

Regarding the formation of slums (subnormal census tract), it is observed that there is a greater demand for allocation of public resources in infrastructure due to the substantial and unplanned increase of the resident population. Moreover, in Rio de Janeiro at AP4 (studied planning area), there is a substantial loss of forests (tree and shrub cover), field (grassy-woody cover), areas subject to flooding and unbuilt areas. It should be noted that a great part of the forest and field that subtracted in the period 2008-2010 is located in the Planning Areas 4 and 5, which is explained by the strong presence of this use in these areas. Still, with respect to AP4, there is a significant loss of forest to favela (this is an area surrounded by Tijuca and Pedra Branca Massif, which has a large number of forests within its urban area). To get an idea, in this period the AP4 lost 9.7 hectares of forest (tree and shrub cover) and 5.3 hectares to the slums (IPP, 2012).

At Table 3 we can see the area occupied by slums registered in Rio de Janeiro and AP4, between 2008 and 2010. In 2010 15% of such slums were located in AP4.

Table 3. Area occupied by slums registered in Rio de Janeiro and AP4

Municipality (RJ) and AP4	Area (m^2)		
	2008	2009	2010
Rio de Janeiro	46,829,483	46,807,142	46,420,263
Planning Area 4	6,995,321	7,021,126	6,981,298

Source: IPP 2015a.

Finally, as to the SDI (Social Development Index), there is an improvement (Table 4). The major real estate projects in Barra da Tijuca, especially residential ones geared towards classes with higher income levels (this region is classified as medium-high socio-economic development), were responsible for the improvement of the SDI, but even so, many aspects were not resolved, among which are sanitation and transport (Cruz et al. 2014).

Table 4. Social Development Index (SDI) in Rio de Janeiro, at AP 4, Planning Area, Administrative Region, Neighbourhoods and City - 2000 e 2010.

City (RJ), AP4, Planning Areas, Administrative Regions and Neighbourhoods	IDS (2000)	IDS (2010)
Rio de Janeiro City	0.58	0.61
Planning Area 4	0.58	0.62
Administrative Region 4.1 - Jacarepaguá	0.56	0.59
XVI Jacarepaguá	0.57	0.60
XXXIV Cidade de Deus	0.53	0.56
Planning Area 4.2 - Barra da Tijuca	0.61	0.67
XXIV Barra da Tijuca	0.61	0.67
Barra da Tijuca	076	0.76

Source: Modified IPP by Census IBGE.

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3.3 Energy and Environmental Assessment

The current mode of production of the city of Rio de Janeiro follows the trend of production of large Brazilian cities, which makes intensive use of energy and other environmental resources, causing potential environmental impacts and greatly compromising sustainability. As demonstrated by Cruz et al. (2004), the Construction Industry is one of the main responsible sectors for energy consumption in the built environment. Energy consumption in this sector is particularly relevant when evaluating the main construction materials in Brazil. Much of this industry is dependent on fossil energy, representing high consumption (Table 5) and resulting in higher CO2eq emissions (Table 7).

Table 5. Energy consumption in Brazil, by sub-sector of built industry - 2010-2013.

Sector	Consumo 103 tEP			
	2010	2011	2012	2013
Cement	4,157	5,049	5,151	5,316
Iron/Steel	16,445	17,401	16,914	16,275
Ceramic	4,485	4,724	4,803	5,069
Total	25,087	27,174	26,868	26,660

Source: EPE 2014.

Table 6. Intensity Energy (tEP) by subsector of the building industry / m2 and a total in AP4 - 2010.

Subsector	tEP/m2	tEP AP4
	2010	2010
Cement	0.0110309637	14,695.42
Iron/Steel	0.0023644938	3,149.97
Ceramic	0.0037132353	4,946.76
Aggregates	0.0065321077	8,702.05
Roofing	0.0494666700	5,737.69
Total		37,231.90

Source: Development from Cruz et al. 2004.

Table 7 presents a result of C02eq emissions above 170 thousand tons in 2010, which is 0.26% of the cumulative emissions that year in the metropolitan area of Rio de Janeiro State, including all productive sectors according Inventory of GHG emissions in Rio de Janeiro state, published by the Climate Center (2013).

Table 7. CO2eq emissions by sub-sector of the building industry in Brazil and in full AP4 in 2010.

Sector	ton CO2eq / m2	ton CO2eq AP4
Constructed Area		1,332,197m2
Cement	0.05984661	
Iron/Steel	0.00475596	
Ceramic	0.02948056	
Aggregates	0.01910509	
Roofing	0.01670053	
Total	0.1298887483	173,037.40

Source: Development from Cruz et al. 2004.

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In financial resources the value could be estimated at approximately EUR $ 26.00 per CO2eq ton avoided, representing EUR $ 4.5 million, or equivalent to the cost of production of 200 standard 46m2 MCMV affordable housing (Cruz et all, 2014), which would serve a population of approximately 1,000 people with income between 0 and 3 minimum wages, which is the poorest group of the population.

4. CONCLUSION

Analysed sectors show the importance of housing construction in Brazil, particularly given the population growth scenario expected by the middle of XXI century in the higher growth areas such as Planning Area 4 - AP4 in Rio de Janeiro. As seen above this scenario indicates a power consumption estimate of 1.77TWh every decade, i.e. in five decades 8.5TWh would be needed only to supply the market of housing construction in AP4. As for the greenhouse gas emissions (GGE) in the housing construction sector in AP4 it could represent the equivalent of EUR $ 45 million in each decade, enough to build more than 10,000 affordable housing by 2050.

O contexto estudado indica a necessidade de alterações subtanciais no modo de produção da indústria de contrução civil no Brasil buscando a redução significativa dos recursos energéticos e ambientiais com a adoção de tecnologias e materiais de menor intensidade energética e consequente redução de emissões de GEE o que pode proporcionar a redução dos impactos negativos sobre o meio socioeconômico e ambiental com a melhoria no cenário de sustentabilidade no Brasil.

The studied context indicates the need for substantial changes in the production mode of building industry in Brazil seeking a significant reduction of energy and environmental resources, with the adoption of less energy-intensive technologies and materials and consequent reduction of GHG emissions which may provide the reduction of negative impacts on the socio-economic and environmental aspects, as well as the improvement in the sustainability scenario in Brazil.

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