Globalization and consumption: a case study of cool roofs as a socio-environmental alternative

Globalização e consumo: um estudo dos telhados brancos como alternativa socioambiental

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ABSTRACT

Globalization and consumer society are discussed in their environmental biases and with a transition between global and local scale. From experimental research, the effect of white roofs for temperature reduction in internal buildings at São Borja-RS is investigated. Practical experimentation makes use of habitats, with asbestos cement tiles. Graphs and statistical analysis were used in the study. It was verified that, in days of sun predominance, the habitations with white tile had 2 °C of temperature less than the gray tile, being this smaller in cases of cloudy or rainy weather. It has been estimated that, as a consequence of the lower temperature under ideal conditions, a white tile will result in a reduction about 4.4 kWh/year/m² in electric consumption with air conditioner, which translates into approximately R$ 2.00/year/m² (energy values at São Borja). Despite the appreciable reduction in average temperature, the financial return will be in the long term.

Keywords: Domestic Economy. Sustainability. White Roof. Consumer Society.

RESUMO

A globalização e a sociedade de consumo são discutidas em seus vieses ambientais sob uma transição escalar do global para o local. Enquanto o efeito dos telhados brancos para redução de temperatura interna em edifícios de São Borja-RS trata da parte prática. A experimentação prática faz uso de habitáculos, com telhas de fibrocimento. Gráficos e análise estatística foram empregados no estudo. Verificou-se que, em dias de predomínio de sol, os habitáculos com telha *branca apresentavam 2°C de temperatura a menos em relação a da telha cinza, sendo essa diferença menor em casos de tempo nublado ou chuvoso. Calculou-se que, por consequência da menor temperatura, sob condições ideais, uma telha branca irá resultar em uma redução de cerca de 4,4 kWh/ano/m² em consumo elétrico com condicionador de ar, o que se traduz em economia de aproximadamente R$ 2,00/ano/m² (valores da energia em São Borja). Apesar da redução apreciável na temperatura média, o retorno financeiro é em longo prazo.*

Palavras-Chave: Economia Doméstica. Sustentabilidade. Telhados Brancos. Sociedade de Consumo.

1 INTRODUCTION

With growing energetic demand, coming from the expansion of development based on production and consumption that adapts and globalizes from mercantile capitalism, intensified after the recent technological revolutions, the degradation of natural capital occurs at an accelerated pace (MILLER and SPOOLMAN, 2013) Among the environmental problems generated, Goldstein (2009) exposes the increase of greenhouse gases emission (GGE), which brings as its main consequence the global warming.

With the advent of industrial revolutions and the consequent shift in the development of societies, cities are gradually becoming the *locus* of human. Changes in the territorial organization with the development of national states and the legitimacy of private property as a pillar of the current social organization led to an intensification in urbanization. However, only when technology reaches the countryside (Green Revolution) does the urban area start to concentrate populations, also in less developed countries.

Since the Cities and Biodiversity Outlook (2012), even considering the best scenarios, the urban areas will reach, until 2030, from two to five times more than now. It implies in a series of environmental consequences, as exacerbated consumption of water resources and agricultural land, a considerable loss of biodiversity and ecosystem services, add to consolidating climate change from local to global scales. In the same document, it exposes that the tendency to increase urban areas occurs preferably in less developed countries.

In this context, local scales of analysis present a list of problems related to the climate, which the thermal inversion, urban canyons, acid rains, heat islands, among others.

It is a fact that the highest concentration of humans occurs in intertropical and temperate northern thermal zones. The first one is remarkably hot and the second, with intense summers and winters in most of its climates, favors the use of appliances with the function of conditioning the air in restricted environments. It is worth mentioning that such equipment requires large amounts of electrical energy for its operation, and that the production of electrical energy directly involves the degradation of natural capital, as well as many times, the elimination of important environmental services to a greater or lesser degree.

One of the alternatives to avoid excess health, on the summers, at the edifications, and then avoid the indiscriminate use of home appliances and electrical energy to cool those places, are the cool roofs (white or green). White roofs painted by clear colors avoid the health excess. The green roofs are denominated since it is a vegetal cover, avoiding the sun exposition of buildings.

This study will discuss the relation between the city, the consumption society, and the environmental consequences of this process at different scales. The main goal will be featured in an experimental study to evaluate the technician of the cool roofs for buildings considering the geographic conditions of São Borja-RS.

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2 FROM CONSUMER SOCIETY TO UNSUSTAINABILITY OF URBAN ENVIRONMENT

The more recent facet of capitalism is the use of information in real-time. Since it's become, practically hegemonic, the real-time information taken on civil meaning and turn itself a triumph of the biggest corporations per consumer goods' industry and financial market. Therefore, globalization earns velocity and intensity. Santos (2011) claims the process is perverse, and there is an urgent need for changes in the logic of globalization, keeping the characteristics of communities without enforcing a socioeconomic and sociocultural homogenization.

In the productive context, Ortigoza (2009) explains that with the informational capitalism, the main productive activities are organized with a global way taking use of a geographic network, also global, of production, competition and consumption and this structure reaches local networks homogenizing them at. Santos (2005) says that networks own character of materialism and action, being the mean by which pass the production, the good's movement, and the information. To Santos, this is how the universal is transposed to local scales.

As a product, geographic space will be consumed. It happens, as says Ortigoza (2009), by global pressure which creates public management organized to attack the capital, passing by cities homogenization to the detriment of the real population's necessity. It is worth noting that in this production-consumption logic, in the informational capitalism, the governments are seeing as articulators among owners of the mode of production and the consumers. Meanwhile, the small communities are ultimately materialized the production process at its landscapes. This process is the meaning characteristic of the actual international's division of labor, deterritorialization and national's states weakening at the neoliberal's logic.

These socio-spatial dialectics are directly linked with a consumption necessity that emerges, then, for the system's maintenance. The social relations are calculated by the capacity to obtain products, the 'get' overwhelm the affective moments of life. Inside of this logic, the consumption will be the greatest manager of global society, turn to object even the proletarians and their way of life, also. Lefebvre (1991), explains that this is the consumption society, society of ephemeral, of planned obsolescence, of the constant necessity of 'get'. In this context cities are consumption's spaces and the urban way of life is the cities substance.

The relation with the environment is evident in this context. Cortez (2009) expounds that the environmental crisis is also social, and this modus operandi is environmentally unsustainable, socially unjust, and morally indefensible. This affirmation resolves around of the environmental system fail to supply the increasing demand created by this same production-consumption itself, of environmental crisis who destroys the ecosystems regenerator's capacity, and concentration of wealth. The concentration which recently grew in developing countries is back to growth into developed countries (UNITED NATIONS, 2020).

Although, when the perception of the trigger process of the environmental crisis is emphasized, new points of view are proposed. The international conferences that occur time by time, for decades, for countries to discuss improvements about the global environment, show how these questions become political and economic. Examples of it were the confronting proposes of zero-development (zero-growth) and third countries' propose of developing by any costs, nowadays the discussion about and how it would work a "Green Economy", and, which level of global warming will be accepted.

What is observed, as a result, as illustrated by Cortez (2009), is the responsibility's transfer in environmental terms: Governments and Markets are allied, into a perverse logic, put the responsibility on consumers. At the same time, they must adapt to new technologies, new products, increasing consumption, creating new markets and don't abandon the lasts.

As from these ideas, new concepts are created, as "responsible consumption", "conscious consumption", "ethics and cooperative commerce", "green consumption" or, still, "sustainable consumption".

For Toni et al. (2010) “conscious consumption” would be an environmental and socially responsible lifestyle. Cortez (2009) explains, ethics and supportive commerce relate to the whole productive chain, from primary producer to consumer, but don’t argue explicitly about environmental issues. However, that one becomes fundamental when ethics will involve each life aspect on Earth.

Responsible consumption dealing with costumers and your rights, and, must claim to understand the whole production process: origin, prices, value’s distribution, earns of the producers and traders, etc.

A different designation, adopted by the market, is “green consumption”, according to Consumers International manual’s (2005). Its objective is to provide for consumers the choice of power for products that, in its production chain, do not cause environmental problems. The critical to “green consumption” occur when just a few brands can distribute their products to customer markets, constraining the consumer’s choices to few possibilities. Furthermore, the green costumer just pays attention to the tech aspect and usually consumes expanses products, so, the biggest part of the population can’t be a green costumer. Another concept tries to put together both perspectives: Sustainable consumption. Although, regardless of the term used, Cortez affirms:

> Most of the people in industrialized countries continue on a rising consumption route and many others, in developing countries, stay stuck in poverty. To promote a new role to consumption, any vision will need to include answers to four key issues: If global consumers class will have a better quality of life caused by their growth level of consumption; If societies may have the consumption with a balanced way, especially harming the natural environment with consumption; if societies can reshape consumer options for genuine choice; and if societies can prioritize or meet the basic needs of all (CORTEZ, 2009, p.59).

Considering cities as consumption spaces and dwelling place of humans, it is observed that despite the rhetoric, increasingly focused on sustainability. In countries less developed this is a distant reality. Davis (2006), in his review work, concludes that this is a Planet of Slums. In a chapter called “Slum Ecology”, he puts in evidence the socioenvironmental result of exclusion and marginalization process, the union of inhumanity condition of life allied with extreme insalubrity, as well possible predictable natural disasters. Thus, despite the fast city’s growth, the population’s wellbeing, which depends on environmental quality, does not keep pace.

The Cities and Biodiversity Outlook (2012) shows that rates of urbanization, in South American countries, are bigger than, for example, European developed countries. This process was intensified by military governments, who, from the sixties to eighties, foster, in the region, economic politics based on green revolution in the agricultural sector, without making an agricultural land reform promoting conflicts in the fields and disorganized urban expansion.

“Green Revolution” was a group of technologies proposed, in the sixties, by developed countries (mainly the US) as a solution for the problem between population growth and food production. Novaes (2012) explains the main consequences of this process: changes at land’s primitive accumulation cycles that to establish violence, stole and land fraud as a process (Murder of leaders, indigenous land’s invasion, public’s conservation units, manual and intellectual expropriation of the traditional population, forced migration); private land’s expansion connected to multinational companies, implementation of technology and machinery, transgenic seeds and pesticides that just a few companies own patents.

This millennium for the first time in history occurred an inversion between rural and urban areas, on a global scale (United Nations, 2019). Nowadays, more than 50% of the world’s population lives in urban areas, and the prediction for 2050 is 70% and a third part in slums. A large part of this urbanization process is related to the green revolution, but, once sold by developed countries, through the United Nations (UN), as a solution for world hunger, helped a fast and large-scale rural exodus in developing countries (NETTO, 2013).

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Therefore, by more theoretical-conceptual instruments, technological tools or even in uncounted politics, the environment is thought of as a secondary meaning compared to the attention paid to economic development. After almost 20 years, words of Santos still demand attention, may the results of all the process suggest an intensification of urbanization, labor's expropriation by rural exodus and inequality expansion in the cities (DAVIS, 2006) and reification of the environmental issue who becomes a product (CORTEZ, 2009) more and more meager in urban landscapes, even being inherent for earth's life.

3 CONTEXTUALIZING THE WHITE ROOFS

Using a scale appropriated, the previous discussion should be tuned specifically to the urban space. The attempts to establish an order in this intense human-nature relationship go through planning. Monteiro comments that:

> By encompassing the natural foundations that outlined the first elements of a space that added the entire social product of work, mirroring a culture, the city encompasses political action (moral and ethical), aesthetic mediation, reconciling the functional use with the beautiful, in a highly accumulated congregation of conflicting interests, requires the validity of a social pact, governed by a legal order that ensures adequacy and equity to what is produced by the technique. (MONTEIRO, 2008, p.80).

In practice, there are many difficulties to overcome an economic view of space that materializes in hostile relations towards nature, especially in the urban environment. However, paying attention to environmental issues, it is a fact that human beings need environmental quality: clean air, clean water, agricultural land, among others, and became developed. (NUCCI, 2008).

Considering the weather, Lombardo (2009) explains that the relation between global and local scale is extremely complex and does not occur in a simple model. Moreover, the influence of city temperatures is irrelevant to the global size, once the build surfaces are only 1% of the terrestrial surface. However, concerning the launch of GHGs, the current consumer society is extremely relevant:

> Due to the increase in energy expenditure (for domestic use, transportation, for industrial purposes, among many others, dictated by a constant need to reduce distances and raise the standard of living (KANN, 2006), cities are the most important sources GHG emissions, contributing about 85% to the total emissions of CO2, CFCs and tropospheric O3 (OKE, 1997). The high density of pollutants in the urban plume affects the chemistry of the atmosphere and the climate on a large scale (CRUTZEN, 2004). According to some authors, the increase in convection, as a result of warming over urban areas, may contribute to the transport of water and pollutants to the medium and high troposphere, with potential consequences at regional and global levels (CRUTZEN, 2004; SHERWOOD, 2002) (LOMBARDO, 2009, p.116).

She continues and explains that in a general way, there is troubles associated with changes at radioactive balance, alteration near atmosphere circulation, an increase of atmospheric pollution, convective precipitation, and formation of urban heat islands (UHI), all of these created by environment degradation which anthropic origin.

Talking about the UHIs phenomena, Costanzo et al. (2016) attribute to the high population density additional warming, which would characterize the phenomenon. Amorim et al. (2009) explain that the main definition of UHIs is the differences in land use that exist between areas with building density, the concentration of materials with great energy potential for emissivity and reflectance, as well as urban activities that release heat in the surrounding atmosphere, and also areas with characteristics opposite to these (rural or peri-urban). This effect, coupled with the fact that there are regions on Earth that, at least during certain periods, are naturally hot and humid, boost the demand for equipment that alleviates the sensation of heat, such as fans and air conditioners. Such equipment, despite making an isolated environment more comfortable, contributes to the launch of GHGs through energy consumption and, sometimes, the equipment itself.

For example, an air conditioning of 12.000 BTU/h will do, besides transfer almost 3,5kJ of energy per second (heat pull out of ambient – approximately 3,5 kW) from ambient to another, to dissipate energy with a power of approximately 1 kW, mainly because of the electric consumption of the equipment, as related by Ananthanarayanan (2013) and Tipler and Mosca (2012).

Cortez (2009) comments that there was, in Brazil, energetical loss higher than 50% in terms of refrigeration of commercial buildings, its uses would not be rationalized, and adequate equipment was not used. It was only in 2018 that the maintenance of air-cooling equipment becomes mandatory for public and private service environments, according to the Law 13.589/18.

Lombardo (2009) explains that among the motivations to UHI existence are: heat emission of anthropic origin; different materials with the capacity to accumulate thermal energy during the day and release it at night; changing the roughness of urban sites; reduction of evapotranspiration due to the lack of free building spaces with the presence of vegetation; changes in the radioactive balance due to the construction materials and the colors used on the surfaces.

Considering the UHI effects on the human being is important to stand out the thermal comfort of the species. The subject matter is a little bit controversial because cultural aspects imply in variations of the ideal temperatures. However, some measurements can be introduced, as in Figure 1, to analyze relative humidity and temperature.

The planning, in this way, suggests active solutions in the face of the urban climate and the creation of a system of free spaces, afforestation, green areas, and exposure of water slides. These solutions can generate improvements in thermal comfort, stabilization of surfaces, better air quality, and decrease of the sound pollution, among others.

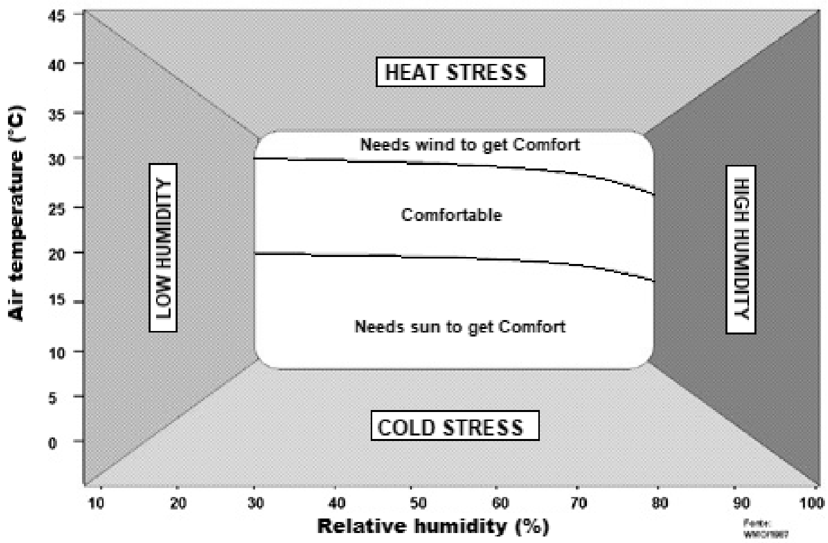

Figure 1 | Human thermal comfort.

Source: Portal do Instituto Nacional de Meteorologia, 2020.

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At building the residences, when solar radiation reaches the roof surface, some of the energy is reflected, and all the remains are absorbed (SABER *et al.*, 2012). The absorbed part results in an increase in the temperature at room surface, and consequently, an increase in the residence temperature. Because of it, under unfavorable conditions, the sunlight absorbed increases the cooling costs in buildings and houses with air conditioning, worsens thermal comfort and mortality during heatwaves, according to Sproul et al. (2014). Therefore, the development of alternative systems to minimize these effects is beneficial for society and the environment.

One of the existing alternative systems is the photovoltaic panels. The use of these panels on the roofs maximizes the use of solar energy by absorbing it and converting it into electrical energy. However, Beise (2004) explains that due to its still relatively high cost, this kind of alternative medium has little use, except for higher social classes. Other alternatives, suggested by Saber (2012) and by Sproul (2014), are painting the roofs with light colors, a proposal called the white roof and the cultivation of plants on the roofs and slabs called green-roof.

A partially or entirely covered roof by some vegetation is called “green” (SPROUL *et al.*, 2014). This characteristic gives to the green roofs the capacity, according to Smith e Roebber (2011), to cool the room – via an effect called cooled by evaporation – provision of habitat for biological life, improvement of air quality through the filtration of pollutants, some thermal insulation, among others.

About the white roofs, Ramos (2017) explain it via the application of reflection property of light colors, resulting in lower thermal absorption. The principle that justifies white tiles use, which goal is to soften the temperature in an inner room in comparison to the external place, occurs by the fact of the cover of a build, during the day, is under constant sunlight. Therefore, the luminosity will be converted into thermal energy, warming the inner room, an unwanted effect at hot weather (TESTA e KRARTI, 2017). To Levinson and Akbari (2010), in those situations, to reduce the thermal gain of the roof, advantages occur in reducing electrical consumption, since the use of electronic equipment designed for this purpose will not be the same (fewer hours of use during the day).

The white roof is explained by a physics phenomenon that light colors reflect more sunlight, going to lower energetic and thermal gains. Generally, roofs are painted with some white paint or acquired with this color, being used mainly in hot weather, due to the “heat” reduction. Because of its simplicity and easy application, the white roofs are strongly considered as an alternative to the thermal comfort and less use of air conditioning (LEVINSON E AKBARI, 2010).

The temperature is a measurable property of a system that expresses the kinetical energy inner it, that is, the molecular agitation. The Law Zero of Thermodynamics states that two or more bodies with the same temperature are in thermal balance (HALLIDAY *et al.*, 2009). This thermal balance is the natural state in which bodies not isolated tend to stay. For multiple bodies in different temperatures, the thermal balance will occur with energy flow among them, by either conduction, convection or thermal radiation.

The heat transfer by conduction, considering any cabin, will occur between the external air and the tiles of the build, and to minimize the heat inner the room, the thermal conductivity of the materials must be as small as possible. The color of the roof does not affect this property, so is not relevant to treat the white roof, but very important to apply regarding thermal insulation and heat reduction.

Siegel (2001) explains that all substances with a temperature higher than 0K lose energy via electromagnetic waves. This phenomenon is called thermal radiation. The radiation emitted by substances has any frequency levels, being the most common those located between infrared and visible light.

In the context of white roofs, it is important to know about thermal radiation and emissivity to recognize that the painting of a roof may or not have a significant effect, depending on the material on which it is applied, but it does not directly depend on the color of the paint.

Regarding wave phenomena, both reflection and absorption are relevant to white roofs. Once the roof is white, that is, it has all the colors of the visible spectrum reflected from itself, it will be absorbing only a part of the energy involved, avoiding the unnecessary entry of thermal energy into the room. White roofs can be improved, according to Xue et al. (2015), if they have a white coating based on a styrene acrylate copolymer, which can cover the entire visible spectrum and a large area of the near-infrared.

The city of São Borja, as most of the cities from the Rio Grande do Sul, is classified, according to Instituto Brasileiro de Geografia e Estatística (IBGE, 2018), as mild super humid mesothermal climate, that is, with average temperatures between 10 °C a 15 °C and without drought periods. Once the ambient temperature on the summer exceeds 40°C, higher than the tolerance range for human thermal comfort, the use of air conditioners and fans to soften the "feeling of heat" becomes a frequent action and constitutes a favorable location for the use of sustainable roofs.

4 METHODOLOGY PROCEDURES

The research makes a theoretical revision about the globalization process nowadays and discusses themes of consumption, planning, and environment urban troubles. It shows alternatives for heat reduction at builds.

The experiment consists of monitoring and register, by automatic thermometers, the inner temperature of two wood cabins with fiber cement roof tiles, one painted in white and another painted in gray, searching to verify and quantify the temperature difference in the environment as a function of roof tile color.

4.1 FIRST STEPS

Using three digital thermometers *data logger*, contact kind, with inner memory to save the data, of *Instrutherm*® enterprise, HT-810 model. Some tests performed to calibrate it, verify if the units are showing the same temperature, being in same the conditions. In a few days, the thermometers were disposed side by side, recording the temperatures. The difference between them was minimum (lower than 0.1 °C).

Two identical cabins were made, built of pinewood and with the following dimensions: Lenght - 1m; width – 1m (1m² of the area); 0.7m of height (Figure 1), organizing the cabins by following the proportion of a middle-class house in the region.

Figure 2 | Image of cabins with gray and white roofs.

Source: Author, 2017.

A tile roof of fiber cement with a thickness of 6mm and 2m length x 1m width, cut in two equal pieces of 1m² each, to stay without clearance above the cabins.

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4.2 EXPERIMENTAL SETUP 1: CHECKING OUT AIR TEMPERATURES

All the preliminaries tests, as well as some definitive experiments, measured the inner (air) temperature inside the cabin. In these cases, the thermometers installed to measure the inner temperature were placed in the center of the box facing north, at a height of approximately 40 cm above the base of the box. To avoid direct heating due to the wooden walls, small Styrofoam plates placed between the thermometers and the walls, totaling around 2cm thick.

4.3 EXPERIMENTAL SETUP 2: CHECKING OUT TEMPERATURES WITH WATER

After the analysis of data obtained only with air experiment, it was found that temperatures varied very sharply, fluctuating very quickly compared to what was expected for an indoor residential location. To improve these results, it was decided to use water in the experiment, to create thermal inertia inside the houses.

The experiment with water consists of two 18L cans with 10 kg (and 15kg in another experiment) of water. The thermometers were disposed on the water surface, the cans at the cabin center, with the same distance between can and walls. The water allowed to make basic evaluations of energy.

5 RESULTS

Four experimental tests were done with the thermometers in the cabins, each one in different periods and weather conditions. Each experiment has changed some specific aspects, as the change of the place of room thermometer and measurement of water temperature. The data were collected by a *data-logger* thermometer, which registered it at a rate of one per minute, in all cases.

5.1 SIMPLE TEST WITHOUT WATER 01: AUGUST 2017

The room thermometer was in a place far from the cabins, fixed in a wall with shadow permanently, in a covered area. (Figure 3). Note that the line of air temperature in the white roof gives lower temperatures than the gray roofline, while the room temperature line is a basic reference.

It is possible to see that there are time intervals in which all thermometers were registering similar temperatures. It occurs at night and when the weather was cloudy or raining, situations in which solar light intensity is weaker or null.

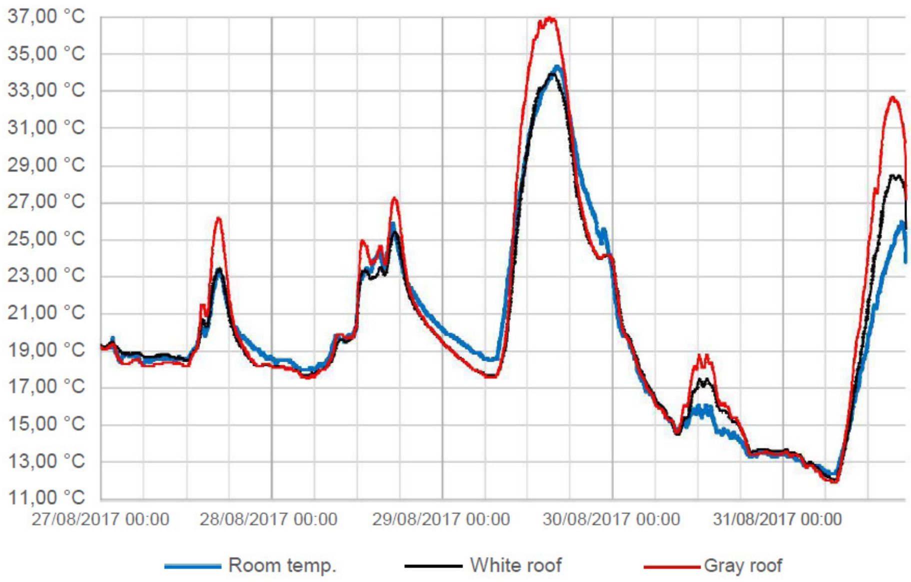
A general arithmetic average of all temperature values was performed between 00:00h of 27th until 17:00 on 31 August. This generally represents a reduction of 0.57 ° C due to the color of the roof.

It considers the night period, where it is not expected any difference because of the roof colors. Making an arithmetic average of the same temperatures considering the only solar light period, we obtain different results, shown in Table 1.

The results of table 1 suggest that the temperature difference during the day is almost always greater than 0.57 ° C. Assuming that only the 29th and 31st of August had full sun, the average daytime temperature reduction was 2.59 ° C, while on a cloudy or rainy day (27, 28 and 30) there was a reduction of approximately 0.65 °C.

With maximum temperature relations, August 29 provided high temperatures. The maximum room temperature reached 34.2°C, while maximum inner temperatures of cabins were 33,9°C (white roof) and 37°C (gray roof), a difference more than 3°C.

Graphic 1 | Results obtained with first experimental test.



Source: Author, 2017.

Table 1 | Arithmetical temperature average of first experimental test, in sunny periods.

Days and intervals	*Test 01 – Average of registered temperatures*			
	Room	*White Tile (TW)*	*Gray Tile (TG)*	*ΔT (TW – TG)*
27/08 – 08HS TO 18 HS	19.96°C	20.07°C	20.61°C	0.51°C
28/08 – 08HS TO 18 HS	22.25°C	21.94°C	22.74°C	0.80°C
29/08 – 08HS TO 18 HS	29.65°C	28.99°C	31.50°C	2.51°C
30/08 – 08HS TO 18 HS	15.09°C	15.95°C	16.55°C	0.60°C
31/08 – 08HS TO 18 HS	20.15°C	22.06°C	24.74°C	2.68°C

Source: Author, 2017.

5.2 SIMPLE TEST WITHOUT WATER 02: SEPTEMBER 2017

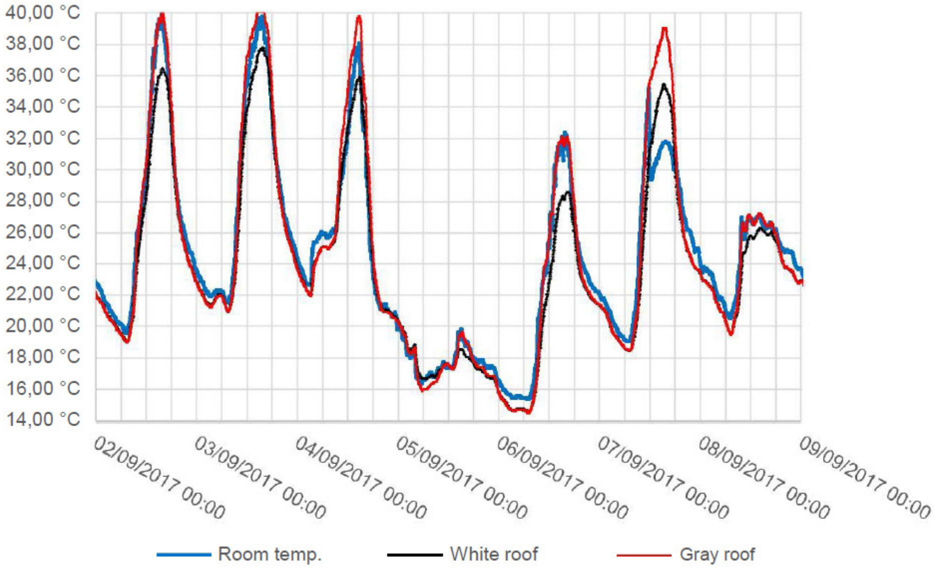
Between the first and nine days of September, another experimental test was made. Now, the unique difference was the local of room temperature thermometer, which is fixed to the outside of the south face of the house with the white tile, separated from the wood itself by two 10mm plates.

The data between the Day 2 until 00:00hs of the ninth day (complete data), gives similar results as the test before, a reduction of 3° in the daytime (Figure 4).

Making the arithmetical average of the periods with some incidence of sunlight, as made before, the data shown in Table 2 are obtained, which points to an average temperature reduction about 2.20 °C, at best, and below 1.00 °C in unfavorable situations (with low solar radiation).

Although the results considering only the air temperature be partially consistent with each other, it is not possible to verify, intuitively, the economic viability with those data alone. Besides, the inner temperatures of the cabins varied very quickly during the day, becoming like the ambient temperature in a short time, a fact that was not expected for a full-scale house, whose internal temperature oscillates more slowly.

Graphic 2 | Data obtained with the second experimental test.



Source: Author, 2017.

5.3 TEST WITH WATER: SEPTEMBER 2017

Since the fast variation of inner temperature verified in the previous tests, search to introduce elements that increase the capacity and thermal inertia inner the cabins. We choose to use water because its specific heat *c* is higher than other materials (4.18J/g * K) (BAUER et al., 2013).

The test made between the 19th and 21st days of September and the data is in Table 2. It is possible to see that the inner temperature oscillation is more smooth to those lines of room temperature, even with an all sunny day (Figure 5).

Table 2 | Average temperature at day periods of the second experimental test.

Days and intervals	*Test 02 – Average of registered temperatures*			
	Room	*White Tile (TW)*	*Gray Tile (TG)*	*ΔT (TW – TG)*
02/09 – 08HS TO 19 HS	31.94°C	30.16°C	32.19°C	2.03°C
03/09 – 08HS TO 19 HS	33.91°C	32.58°C	34.60°C	2.01°C
04/09 – 08HS TO 19HS	30.33°C	30.18°C	32.04°C	1.86°C
05/09 – 08HS TO 19HS	18.00°C	17.67°C	17.86°C	0.19°C
06/09 – 08HS TO 19HS	26.30°C	23.89°C	26.29°C	2.40°C
07/09 – 08HS TO 19HS	29.60°C	29.98°C	32.65°C	2.67°C
08/09 – 08HS TO 19HS	25.92°C	24.95°C	25.78°C	0.83°C

Source: Author, 2017.

From the data, it is possible to do the temperature average (table 3), with similar results that before, with a difference about 2°C at medium temperature (during the day) because of the white color of the roof.

Table 3 | Temperatures average at day periods with first water tests.

Days and intervals	*Test 03 – Average of registered temperatures*			
	Room	*White Tile (TW)*	*Gray Tile (TG)*	*ΔT1 (TW – TG)*
19/09 – 08HS TO 19 HS	32.18°C	25.11°C	27.32°C	2.20°C
20/09 - 08HS TO 19 HS	36.42°C	28.73°C	30.77°C	2.04°C
21/09 – 08HS TO 17H15MIN	35.10°C	28.27°C	29.99°C	1.72°C

Source: Author, 2017.

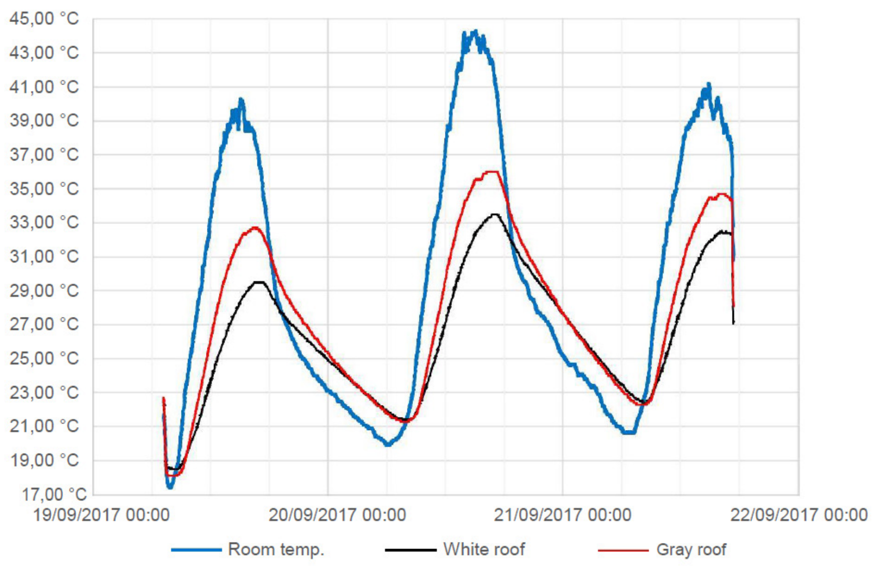
In terms of lower and higher temperatures to each date, our values are been presented in table 4. It enables, together with the difference between these values (ΔT2) of water temperature inner the cabin, the potential value of financial saving.

The temperature variation (ΔT2), water mass (m) (despise evaporation loss) and the specific heat of water (*c*), is possible to evaluate the quantity of thermal energy (Q) absorbed by white and grey roofs, considering the equation Q=m*c*ΔT2 (HALLIDAY et al., 2009b).

With this information, it is possible to convert the caloric value (kJ) in energy, at kWh unity, and, since the energy charge by kWh is R$ 0,452/kWh (São Borja data), is easy to evaluate the financial save considering the roof painted, in comparison a one air conditioning (Table 5).

From the results of table 5, an electric energy saving prospect was calculated based on the experiment which shows, for sunny days, savings of less than half a penny per day for each square meter of cooled painted area (since the miniature houses had an area of 1 m²) roof).

Graphic 3 | Graphic representation of data obtained with water tests.



Source: Author, 2017.

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Table 4 | Values of high and low temperatures to the water in cabins with white and gray tiles.

Date	*Low Temperature*		*High Temperature*		*ΔT2 Difference*	
	White Tile	*Gray Tile*	*White Tile*	*Gray Tile*	*White Tile*	*Gray Tile*
19/09	18.6°C	18.1°C	29.5°C	32.7°C	10.9°C	14.6°C
20/09	21.4°C	21.3°C	33.5°C	36.0°C	12.1°C	14.7°C
21/09	22.5°C	22.3°C	32.4°C	33.6°C	9.9°C	11.3°C

Source: Author, 2017.

Table 5 | Results of the economy considering the first data with the experimental water test.

Date	*Tile*	*ΔT2 (°C)*	*Q (kJ)*	*ΔQ (kJ)*	*ΔQ (kWh)*	*Economy (R$ /day m²)*
19/09	White	10.90	456.27	154.89	0.043025	0.006482433
	Gray	14.60	611.16			
20/09	White	12.10	506.51	108.83	0.030230	0.004554653
	Gray	14.70	615.34			
21/09	White	9.90	414.41	58.61	0.016280	0.002452853
	Gray	11.30	473.02			
AVERAGE				**107.44**	**0.029845**	**0.004496646**

Source: Author, 2017.

Extrapolating this value to a year of 365 sunny days, there would still be savings of only R$ 1.64 per cooled m², assuming that the environment is cooled by air conditioning throughout the morning and afternoon. Even in these best cases, a 50m² environment would save R$ 82.06 in one year with cooling costs.

The values found for savings with annual cooling costs per m², in the American context, between white tile and black tile vary between US $ 0.1 to US $ 4.0, with an average value of US $ 0.40 for the cases studied, according to Sproul et al. (2014).

Despite the similarity in the order of magnitude of the financial values found in this work and among those cited in the American research, it is not appropriate to compare these values only via monetary conversion, since many variables in the research were different from each other. In any case, financial savings figures of the mentioned dimension are low and imply a slow return on the initial investment.

In energy terms only, using the average value of *ΔQ* present in table 5 and dividing it by 3, under the conditions mentioned, a white painted roof could have the ability to reduce energy gains (in electricity) in something around 3.63 kWh/year for each m² painted and cooled.

Dividing the energy values Q of the white roof by the energy values Q of the gray roof, it is possible to find that there will be an average reduction of 18% in the absorbed heat. If taking into account the efficiency of an air conditioner (dividing the value by 3), it reveals that there will be a 6% reduction in cooling costs.

Of course, how much energy will be discarded will depend a lot on the season and the climatic situation. Nevertheless, the results obtained are lower in comparison to those presented by Synnefa et al. (2007In thi), which identify in their simulation an energy-saving between 9 to 49 kWh / m² / year for different locations.

5.4 TEST WITH WATER 02: OCTOBER 2017

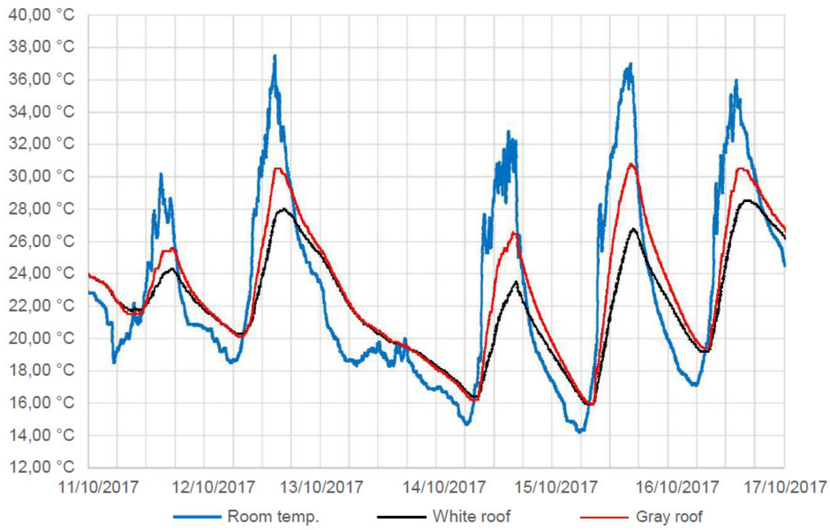
The last experimental test occurs between the 11th and 29th day of October 2017. The same methodology that before was used, since the only variation between the experiments was the water quantity, which now is 15 kg. With a long period of experimentation, the graphic representation will be divided into three graphics, to best visualization (graphics 5, 6 and 7). The vertical axis (each day) is the midnight hour of the day, for all graphics.

An analysis of the graphs shows a huge variation of weather during the whole period of experimentation, with several days whose graphics of room temperature is quite unstable, during the daytime, indicating clouds, rain, or significate winds. The main variability is useful since the real situation is that it will not necessarily be sunny all day.

Applying the same treatment used before to obtain the average temperatures, it is in table 6, which in general gives a medium difference about 1.54°C, a lower number than found previously, but understandable since the high number of days with constant sun.

To evaluate the financial saving, we use the same procedure, with the difference value of the maximum and minimum temperature (ΔT_2) being featured directly. The times for temperature measurement were from 08hs to 16h30min, respectively. The data are in table 7.

Graphic 4 | Graphic representation of temperatures at second water test (October 11st to 17st).



Source: Author, 2017.

In this case, despite the smallest difference between the average temperature cited before, the data of table 7 point daily savings of approximately 0,63 cents by m²of white area and cooled (air conditioning) by day, totalizing R$ 2.30/m²/year saved. In the same way, in energy terms, the predictions are about 5.09 kWh/m²/year saved.

Regarding the percentages, there is a prospect of savings around 9% with air conditioning costs, since the white painted tile will absorb almost 27% less thermal energy than the gray tile.

In general, using the results of all experiments, there was an average temperature reduction of approximately 2°C for sunny days and values below 0.5°C for situations in which the weather is not favorable, generating potential savings of nearly R$ 2.00 / year per square meter painted and cooled, which would also translate into 4.40 kWh / year / m² in electricity.

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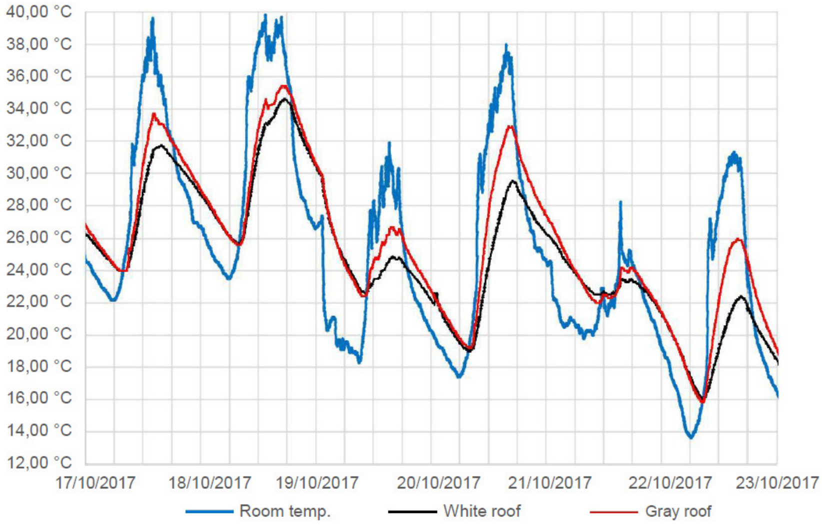
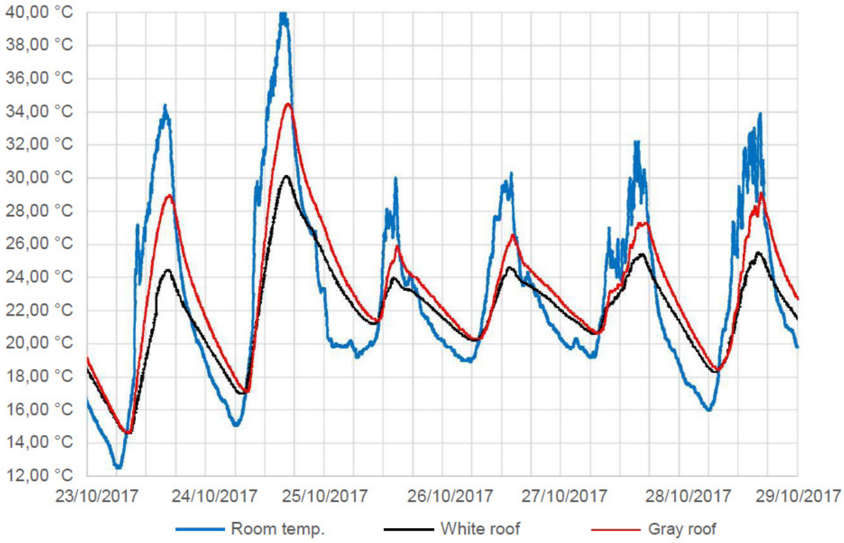
Graphic 5 | Graphic representation of temperatures at second water test (October 17st to 23st).



Source: Author, 2017.

Graphic 6 | Graphic representation of temeratures at second water test (October 23st to 29st).



Source: Author, 2017.

Table 6 | Temperature average during the day for the second test with water.

Days and intervals	*Test 04 – Average of registered temperatures*			
	Room	*White Tile (TW)*	*Gray Tile (TG)*	*ΔT1 (TW – TG)*
11/10 – 08HS TO 19 HS	22.70°C	22.91°C	23.51°C	0.60°C
12/10 – 08HS TO 19 HS	29.87°C	24.98°C	26.63°C	1.65°C
13/10 – 08HS TO 19HS	19.02°C	20.13°C	20.21°C	0.08°C
14/10 – 08HS TO 19HS	26.72°C	20.60°C	22.94°C	2.34°C
15/10 – 08HS TO 19HS	29.80°C	22.46°C	25.46°C	3.00°C
16/10 – 08HS TO 19HS	30.19°C	25.35°C	26.95°C	1.60°C
17/10 – 08HS TO 19HS	33.35°C	29.11°C	30.40°C	1.29°C

Days and intervals	*Test 04 – Average of registered temperatures*			
	Room	*White Tile (TW)*	*Gray Tile (TG)*	*ΔT1 (TW – TG)*
18/10 – 08HS TO 19HS	36.11°C	31.58°C	32.46°C	0.88°C
19/10 – 08HS TO 19HS	25.88°C	23.80°C	24.82°C	1.02°C
20/10 – 08HS TO 19HS	31.58°C	25.39°C	28.11°C	2.72°C
21/10 – 08HS TO 19HS	22.61°C	22.90°C	22.94°C	0.04°C
22/10 – 08HS TO 19HS	26.06°C	19.79°C	22.41°C	2.62°C
23/10 – 08HS TO 19HS	27.28°C	20.47°C	23.54°C	3.07°C
24/10 – 08HS TO 19HS	31.86°C	25.49°C	27.86°C	2.37°C
25/10 – 08HS TO 19HS	23.77°C	22.65°C	23.46°C	0.81°C
26/10 – 08HS TO 19HS	25.79°C	23.22°C	24.16°C	0.94°C
27/10 – 08HS TO 19HS	26.58°C	23.69°C	24.74°C	1.05°C
28/10 – 08HS TO 19HS	27.05°C	22.74°C	24.44°C	1.70°C
AVERAGE	**27.57°C**	**23.74°C**	**25.28°C**	**1.54°C**

Source: Author, 2017.

Table 7 | Results of the economy considering the second data with the experimental water test.

Date	*Tile*	*ΔT2 (°C)*	*Q (kJ)*	*ΔQ (kJ)*	*ΔQ (kWh)*	*Economy (R$ /day m²)*
11/10	White	2.20	138.14	100.46	0.027907	0.004205
	Gray	3.80	238.60			
12/10	White	7.70	483.48	144.42	0.040116	0.006044
	Gray	10.00	672.90			
13/10	Not applied. No temperature increase was registered during the afternoon					
14/10	White	7.10	445.81	200.93	0.055813	0.008409
	Gray	10.30	646.74			
15/10	White	10.80	678.13	251.16	0.069767	0.010512
	Gray	14.80	929.29			
16/10	White	9.30	583.95	106.74	0.029651	0.004467
	Gray	11.00	690.69			
17/10	White	7.50	470.93	81.86	0.022674	0.003416
	Gray	8.80	552.55			
18/10	White	8.60	539.99	62.79	0.017442	0.002628
	Gray	9.60	602.78			
19/10	White	1.30	81.63	119.30	0.033139	0.004993
	Gray	3.20	200.93			
20/10	White	10.30	646.74	207.21	0.057558	0.008672
	Gray	13.60	853.94			
21/10	White	0.30	18.84	50.23	0.013953	0.002102
	Gray	1.10	69.07			
22/10	White	6.10	383.02	238.60	0.066278	0.009986
	Gray	9.90	621.62			

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Date	Tile	ΔT2 (°C)	Q (kJ)	ΔQ (kJ)	ΔQ (kWh)	Economy (R$ /day m²)
23/10	White	9.80	615.34	276.28	0.076743	0.011563
	Gray	14.20	891.62			
24/10	White	13.10	822.55	257.44	0.071511	0.010744
	Gray	17.20	1079.99			
25/10	White	1.80	113.02	43.95	0.012209	0.001840
	Gray	2.50	156.98			
26/10	White	3.20	200.93	75.35	0.020930	0.003153
	Gray	4.40	276.28			
27/10	White	4.50	282.56	125.58	0.034883	0.005256
	Gray	6.60	408.14			
28/10	White	6.90	433.25	219.77	0.061046	0.009198
	Gray	10.40	653.02			
AVERAGE				**150.70**	**0.041860**	**0.006307**

Source: Author, 2017.

6 DISCUSSING THE PRACTICAL RESULTS

The differences in the roof colors bring a considerable impact at the cabin temperature, with a medium reduction of 2 °C for sunny days. A reduction like it is noticeable, but implies low electricity savings, resulting in a slow return on the investment.

The roof paint installed with white color must not be the main goal to search for electricity saving, but a reduction of internal temperature and better thermal and energetic efficiency of the build. Another justification to use this method in the potential effect to reduces the UHI phenomena in the city, if adopted at large scale, even with inconclusive studies about that effect at the world scale.

By the way, the research agrees with those of theoretical references, since that the temperature reduction implies lower consumption of air conditioners, generates less consumption of electricity and, consequently, less dependence on energy/technology to maintain the thermal comfort of residents.

7 FINAL CONSIDERATIONS

From a model of homogenizing globalization, ruled by the consumption and reification of the space, preferably at urban space, where founds the world population, it was found that environment questions are not incorporated in the guiding policies.

The materialization of this process occurs globally from different scales. For example, the global warming at the world scale, and floods, landslides or climatic troubles as heat urban island frequently reflect social inequalities.

Considering these troubles in the development of the consumer society, it is showed that measures to change such processes may start at local scales. In this context, cool roofs emerge as a viable alternative, because, in addition to the physical aspect related to the climate, it can be leveraged with public policies.

Furthermore, by the technical featured, this work can serve as a contribution to scientific research and can be refined at many aspects, as tests with different cover material, kinds of paints, colors and cabin size.

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