18ª Conferência Internacional da LARES
São Paulo - Brasil
26 a 28 de Setembro de 2018

Financial feasibility studies for the inclusion of sustainable solutions in multifamily housing in Rio de Janeiro

Carlos Stozek Neto[1], Marcelo de Mattos Bezerra[2]

[1] Pontifícia Universidade Católica do Rio de Janeiro (PUC-RIO), Rio de Janeiro, RJ, Brazil, carlosstozek@gmail.com
[2] Pontifícia Universidade Católica do Rio de Janeiro (PUC-RIO), Rio de Janeiro, RJ, Brazil, mmb@puc-rio.br

ABSTRACT

This study investigates the feasibility of using sustainable system solutions in a multifamily apartment complex in Rio de Janeiro, Brazil. The apartment complex consists of thirty-two units in an eight-story building. The four proposed sustainable systems are photovoltaic power generation system, recycling and reuse of greywater, rainwater catchment and individual water metering. The sustainable systems are described in this paper, as well as the parameters commonly used to carry out a real estate development in Rio de Janeiro. Comparative analyses are undertaken between the scenario without the use of any solution and scenarios where the sustainable systems are implemented, in order to highlight the costs and the reduction of consumption generated by each system. The results are used to evaluate details of interest to developers, such as development indicators (IRR, Margin, etc.), need for adjust sale prices and consumers' willingness to pay, as well as details of interest to the buying customer, such as generated savings and payback of the investment. This article shows that in order to match the higher cost of sustainable developments, there is a need to increase the sale price of the units. However, the increase can be justified to the consumer when compared to gains from operating expenses. The results of this study indicate that only the photovoltaic and the individual water metering systems can be classified as attractive, increasing the PSV by 1.28% and allowing a reduction to the customer in the accumulated overall cost over time, of 6.14% at the end of a cycle of 60 years. Consequently, the increase in the price of properties is compatible with the reduction of operating costs during the building lifespan, making the sustainable solutions interesting for both the buying customer and the developer.

Key-words: sustainability, real estate, financial feasibility, multifamily housing, Rio de Janeiro.

Estudos de viabilidade financeira para inclusão de soluções sustentáveis em habitação multifamiliar no Rio de Janeiro

RESUMO

O presente artigo analisa a atratividade financeira do uso de soluções sustentáveis em condomínios residenciais. O trabalho aborda o processo de estudo de viabilidade de um empreendimento multifamiliar hipotético, constituído de um condomínio com 8 pavimentos e 32 unidades de apartamento, no Rio de Janeiro (Brasil), e a inclusão de quatro sistemas: geração de energia solar fotovoltaica, reuso de águas cinzas, captação de água de chuvas e uso de hidrômetros individualizados. São apresentados parâmetros de incorporação comumente utilizados no mercado e a descrição dos dispositivos sustentáveis. Desta forma, são elaboradas simulações comparativas entre o cenário sem uso de nenhuma solução e cenários que fazem uso dos sistemas mencionados, apresentando custos e economias geradas por cada sistema. Os resultados são comparados para avaliar dados do interesse das empresas incorporadoras, como índices de incorporação (TIR, Margem, etc), necessidades de correção nos preços de venda dos apartamentos e disposição a pagar do consumidor, e dados de interesse do cliente comprador, dentre os quais a redução de custos de operação dos imóveis e *payback* do investimento. O artigo evidencia que, a fim de equalizar o maior custo de construção de empreendimentos sustentáveis, há necessidade de incremento no preço de venda das unidades. Porém, estes aumentos são justificáveis perante o consumidor quando comparados aos ganhos com despesas de operação. Os resultados para este empreendimento específico indicam que apenas os sistemas de energia fotovoltaica e de medição individualizada podem ser classificados como atrativos, gerando aumento de VGV na ordem de 1,28% e uma redução no custo global acumulado para o consumidor de 6,14%, isto após um período de 60 anos. Verifica-se assim que o aumento no preço dos imóveis é compatível com a redução de custos operacionais durante a vida útil da edificação, sendo soluções interessantes tanto para o comprador quanto para o incorporador.

Palavras-chave: Sustentabilidade, incorporação imobiliária, viabilidade financeira, habitação multifamiliar, Rio de Janeiro.

1. INTRODUCTION

The increase in the global population and the ever-increasing growth of cities have given rise to various challenges to be overcome in environmental, social, cultural and economic contexts. This situation makes it important to encourage the use of new technological solutions to build more sustainable cities. The real estate sector stands out because it is essentially related to the structuring of the urban environment. Activities in this segment lead directly to the production of new properties and to the renovation of existing ones. Construction, operation and disposal cycles constitute a considerable part of the consumption of natural resources and the gas emissions in the environment. Likewise, the real estate market encompasses the activities of formatting, administration and commercialization of projects that will produce these properties.

With respect to the Brazilian market, the managers of developers currently bear the responsibility of being the decision-makers on the use of sustainable building systems and on the reduction of energy consumption over the lifespan of buildings. However, it is unusual to find multi-family housing developments in the city of Rio de Janeiro that already feature such solutions integrated from the beginning into their designs, thereby demonstrating that real estate developers and buying customers overlook resource management during the development's operations.

Notably, financial considerations govern market relations and it is supposed that the implementation of sustainable solutions is still an unknown variable in terms of financial results. Rogers & Gumuchdjian (2001) mentioned the exposure to long-term capital outlays caused by expenditures that do not directly promote short-term financial returns, making companies less competitive and more vulnerable to financial risks. In addition, consumers do not have clarity on the gains tied to acquiring apartments in sustainable buildings. There is little data on future costs in buildings, which can be explained by managers' limited control over operating costs and lack of transparency on performance data (Goodman, 2004; Weise et al., 2008). Little information is available concerning benefits in ecological terms and mainly, in financial terms, relating to the reduction in operating costs from the use of energy and natural resources during the lifespan of the building.

Here we adopted the principle that financial variables are the main driver for making decisions, both on the part of real estate developers and of buying customers, and the adoption of sustainable practices and systems in buildings can be better evaluated through studies confirming their profitability and financial returns for both stakeholders. This paper aimed to evaluate the financial attractiveness by simulating the use of four sustainable building systems in a hypothetical residential development located in the city of Rio de Janeiro. These systems were: (i) electrical power generation by way of a photovoltaic solar system; (ii) recycling and reuse of greywater; (iii) rainwater catchment; (iv) individual water metering.

The study was focused on providing details that would be interesting to developers, such as development costs, the need for adjustment to sale prices and consumers' willingness to pay, as well as details that would be interesting to the buying customer, such as generated savings and payback of the investment. A secondary objective was to present parameters and strategies used in undertaking a financial feasibility study, according to the practices used by the main developers in the real estate market of the city of Rio de Janeiro.

2. METHODOLOGY

The study began with the assembling of the hypothetical enterprise (object of study), structured according to architectural and commercial aspects frequently applied to developments in the city of Rio de Janeiro. Data was collected on the expected consumption of energy and water during the future operation of the apartment complex, and the sustainable systems were presented with their respective costs and savings. When applied separately in the building, comparative scenarios were created for evaluation from the perspective of two main stakeholders: developers and buyers.

In order to develop the feasibility study, the parameters commonly adopted to carry out a real estate development in Rio de Janeiro were used. The method of the dynamic feasibility study was selected for the real estate development process, without forecasting inflation, considering that possible adjustments for inflation are offset both upon the disbursement of expenses and upon receiving revenue. The cash flow of each scenario was forecasted, resulting in the financial indicators to be used in the analyses.

With respect to financial feasibility focusing on buying customers, the assessment method of discounted payback was chosen, applying a discount rate to covert the cash flow amounts to the present value.

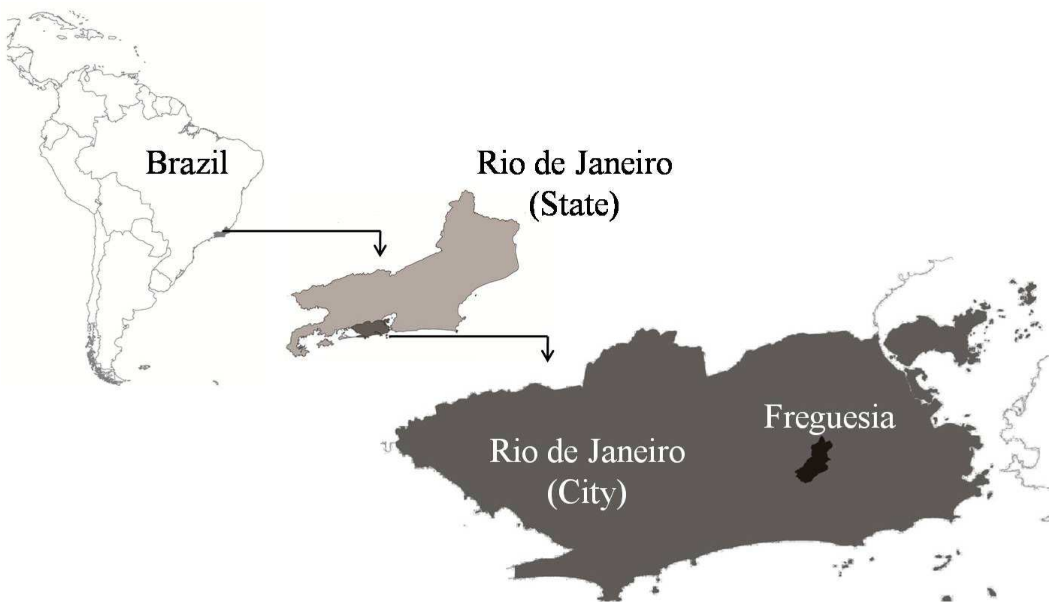
The assembly of the cash flows and the mathematical calculations were generated in a spreadsheet prepared by the authors, using the spreadsheet editor Microsoft Excel.

It is important to note that all price and cost checks were made by the authors in April 2017, using market values found in the city of Rio de Janeiro and/or Brazil, and were duly converted to the US dollar at an exchange rate equal to BRL 3.20 / USD.

2.1. Study object

The city of Rio de Janeiro (see Figure 1) is the second most populous municipality in Brazil (IBGE [Brazilian Institute of Geography and Statistics], 2010), making it an important market in the Brazilian real estate sector.

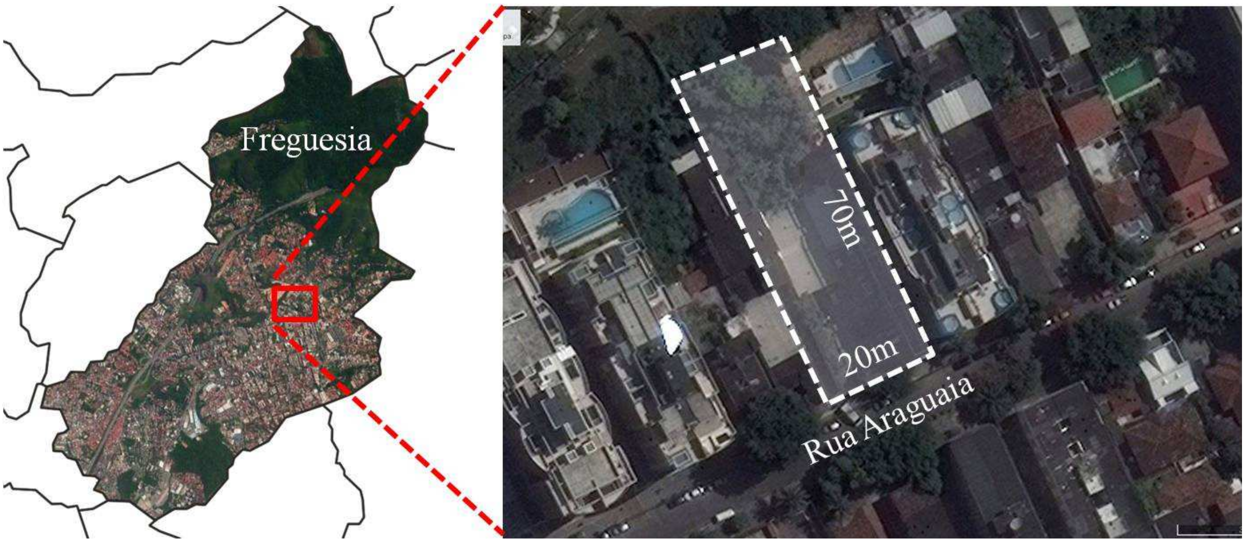
Figure 1 – City location map



Source: The authors

To piece together the hypothetical development, a piece of land situated at Rua Araguaia, in the Freguesia neighbourhood, located in the West Zone of the City of Rio de Janeiro, was chosen (see Figure 2). This region has middle-class residential apartment complexes.

Figure 2 – Land location map



Source: The authors

The development followed the specifications of a R8-N standard design, as stipulated by the Brazilian standard, NBR 12721 (ABNT [Brazilian Association of Technical Standards], 2006). This standard establishes criteria for evaluating unit cost of building in Brazil; the R8-N type was chosen as it is the most commonly used in real estate developments throughout Brazil. The design consisted of a multi-family building with a garage, pilotis, eight stories, normal finishing standards and four units per floor. The standard provides for this model a gross floor area of 5,999 m² and an equivalent built-up area of 4,135 m², in addition to apartment units containing three bedrooms, one being en-suite, a living room, a dining room, a main bathroom, a kitchen and an utility area with bathroom and veranda. The apartments were designed with 92.5 m² each. It is worth mentioning that the building has a roof area of 420 m², which is important information for the sizing of the photovoltaic system and the rainwater catchment system. The external areas related to the land where the building is located are not determined in the standard and were therefore added to the project, resulting in a gross floor area of 6,255 m² and an equivalent built-up area of 4,241 m² (see Table 1).

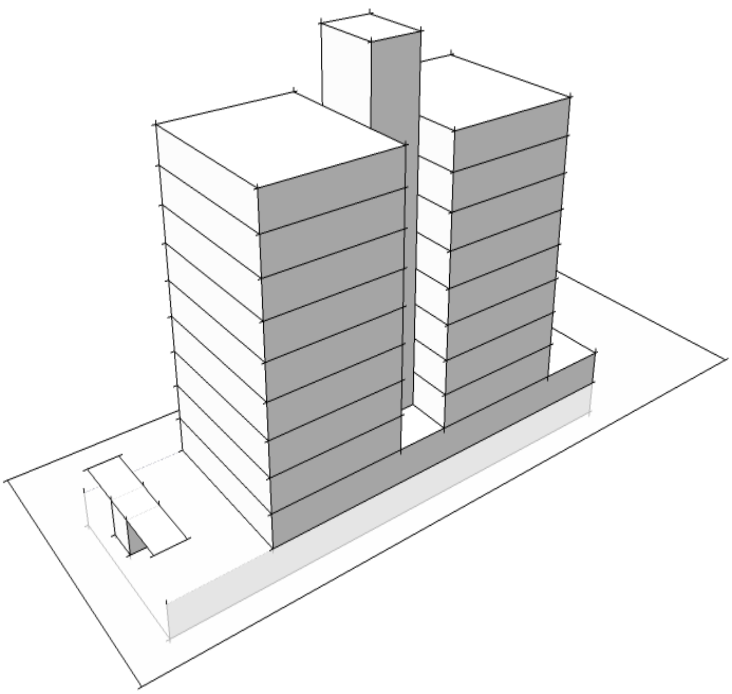
Table 1 – Building areas

Description	N. floors	Floor area [m²]	Equivalence	Gross floor area [m²]	Equivalent built-up area [m²]
Underground level garage	1	950	0.30	950	285
Ground level garage	1	554	0.35	554	194
Sanitary facilities & storage room	1	30	0.50	30	15
Ground level pilotis	1	110	1.00	110	110
Garage roof slab	1	274	0.15	274	41
Typical floor	8	420	1.00	3360	3360
Technical floor	1	271	0.14	271	37
Security gatehouse	1	30	1.00	30	30
SUBTOTAL				5999	4135
External areas	1	676	0,25	676	169
TOTAL				6255	4241

Source: The authors

The schematic model of the project can be seen in Figure 3.

Figure 3 – Basic model of the development



Source: The authors

For this project, families with income over 20 times the minimum wage were selected as the target market. A total of 162 residents and employees were spread throughout the 32 housing units.

The energy and water consumption in the building were estimated in order to determine the costs from these items for operating the development. The energy consumption of the building common areas, such as lighting and electrical equipment, was estimated to be around 2.604 kWh per month for the areas (see Table 2).

Table 2 – Consumption of electricity in common areas of the development

Use	Equipment	Power [Watts]	Quantity	Daily duration [hours]	Monthly consumption [kWh]
Vertical transport	Elevator system	-	2	-	1350
Water Pumping System	Water Pump	2207	1	5	331
Surveillance system	Monitor screen	60	1	24	43
	Microcomputer	80	1	24	58
	Security camera	3,6	8	24	21
	Access gate	186	2	2,4	27
Location	**Type of lamp**	**Power [Watts]**	**Quantity**	**Daily duration [hours]**	**Monthly consumption [kWh]**
Parking Garage	T8 Tubular LED	18	74	6	240
Ground level hall	LED	9,5	15	6	26
Sanitary facilities	LED	9,5	3	3	3
Rubbish storage room	LED	9	2	3	2
Hallways and stairwells	LED	9,5	80	6	137
Technical floor	T8 Tubular LED	18	36	0,2	4
Security gatehouse	LED	9,5	9	24	62
External areas	Sodium vapour	70	12	12	302
TOTAL					2604

Source: The authors

Daily water consumption of 200 litres per capita was stipulated as recommended by the Brazilian standard NBR 12211 (ABNT, 1992). This resulted in monthly consumption per apartment of 1,012.5 litres. Based on the research carried out by several Brazilian authors (BARRETO, 2008; CABRAL ET. AL., 2008; GONÇALVES, 2009), a distribution was made for the use of water in the building (see Table 3). These predictions were important to estimate the reductions in water consumption generated by the solutions here studied.

Table 3: Expected profile for water consumption, by appliance/activity

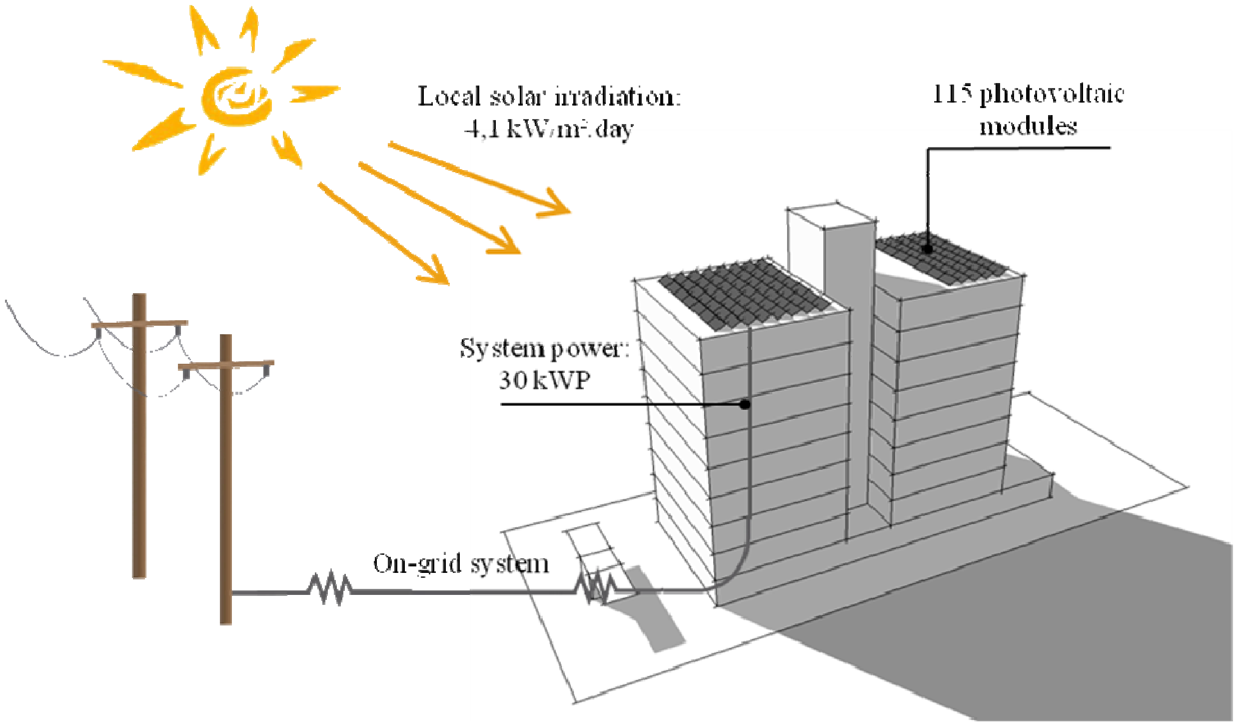
Item	Consumption L/day.capita			
	Barreto (2008)	Cabral et al (2009)	Gonçalves (2009)	Adopted Consumption
Toilet	14.0	-	18-60	18.0
Shower	35.3	-	30-189	50.0
Washing machine	27.7	-	-	16.2
Sink	10.8	-	-	10.8
Laundry sink	13.6	-	-	13.6
Kitchen sink	30.3	-	22,0	30.3
Garden irrigation	-	-	0.6	0.6
Car washing	-	4.1	-	4.1
Floor washing	-	-	-	10.8
Various uses	77.4	-	-	45.6
TOTAL				200.0

Source: The authors

2.2. Analyses of sustainable solutions

As mentioned before, the sustainable systems proposed were the electrical power generation using photovoltaic solar system, the recycling and reuse of greywater, the rainwater catchment and the individual water metering. These systems where chosen as they were the four most valued items in research undertaken in 2014 by a Brazilian research entity, the Sensus Institute (2014).
The photovoltaic power generation system (see Figure 4) was defined as an on-grid system, with an installed capacity of 30 kWp (limited as a result of the area available on the building's roof) and a twenty-year lifespan.

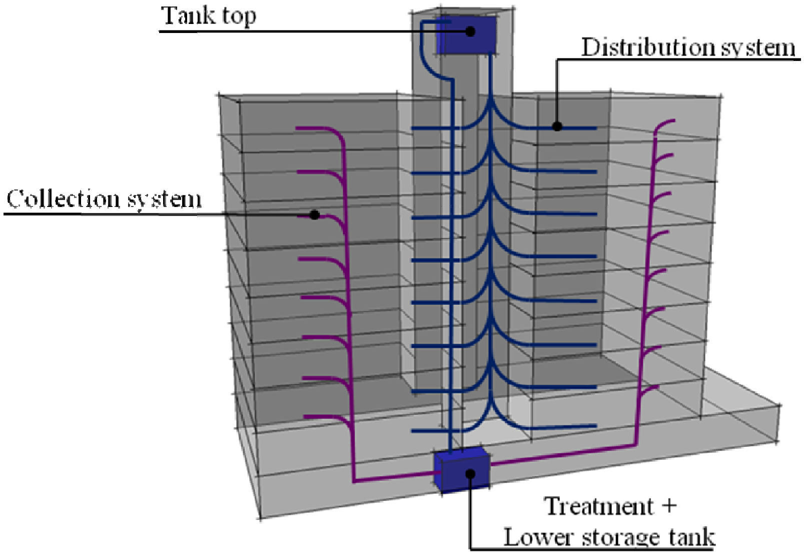
Figure 4 – Photovoltaic power generation system model



Source: The authors

The setup cost was estimated to be USD 44,960.93. A reduction in the energy consumption of approximately 3,690 kWh per month was projected. Considering the amount of USD 0.26519 per kWh charged by the local energy distributor, a monthly net saving of USD 29.65 per apartment was forecast.
The greywater reuse system was adopted based on current legislation in the city of Rio de Janeiro. However, it is worth mentioning that in Brazil there are still no technical standards on treatment and sizing of these systems. Therefore, its size was determined based on the required volume of non-potable water for watering gardens, washing cars and cleaning floors. This met the per capita demand of 33.5 litres per day, giving rise to the need to treat 5,427 litres daily. The treatment consisted in the implantation of a prefabricated treatment station, with anaerobic treatment (compartmentalized anaerobic reactor), aerobic treatment (submerged aerated filter), decanter, equalization tank, tertiary filter and chlorinator. In addition to the station, the pipes for collecting and distributing the system's waters were generally provided (see Figure 5).

Figure 5 – Greywater reuse system model

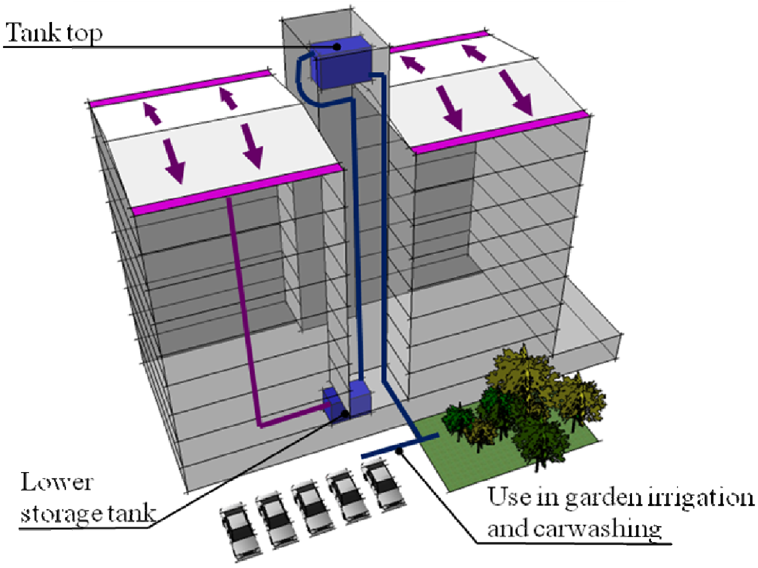


Source: The authors

The cost of setting up the system was calculated based on the additional materials and labour for its construction, resulting in USD 27,576.86. Considering the amount charged by the local water utility in the amount of USD 1.108068 per cubic meter supplied, the reduction in water consumption of 5m³ per apartment projected monthly savings of USD 5.54 per apartment, at an operating cost of USD 3.36 monthly per apartment, leading to a net monthly saving of USD 2.18 per apartment.

The rainwater catchment system (see Figure 6) was designed for a storage capacity of 10 m³, calculated according to the local legislation, the rainfall regime, the roof capture area and the capacity of prefabricated reservoirs available in the local market. It was decided to direct the water collected to be used in watering gardens and washing cars, which configured daily per capita demand of 4.7 litres, and monthly of 22,842 litres of non-potable water for the apartments complex.

Figure 6 – Rainwater catchment system model

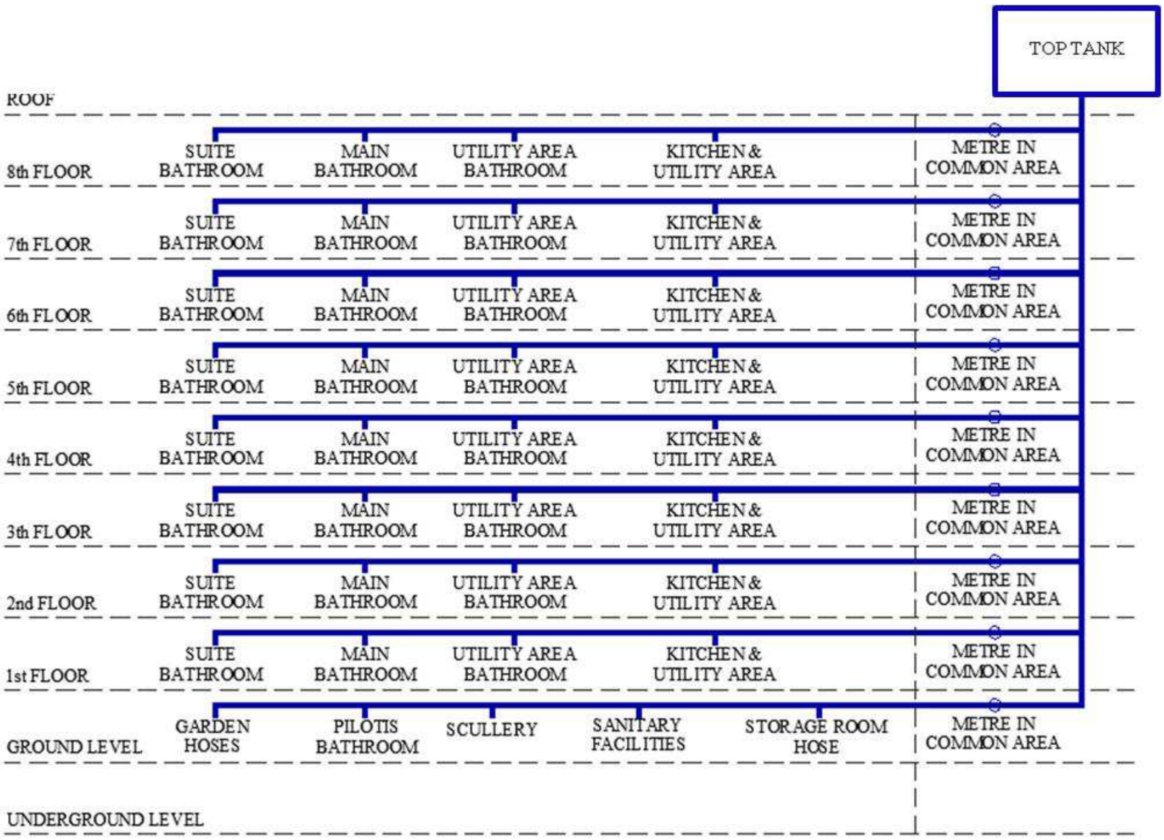


Source: The authors

The total cost of implementing the system was calculated as USD 5,096.60. It was discovered that, due to the local volume of rains, in the months of August, September and October it would not be possible to cover demand for 22m³ in full, which would lead to the need of supplementing the demand with potable water from the local water supply company. Considering again the amount of USD 1.108068 per cubic meter charged by the local water utility, the monthly net saving per apartment was expected to reach USD 0.69, the monthly operating cost being USD 1.83 per apartment, leading to a negative monthly result of USD 1.13 per apartment. These calculations demonstrated that for this development the rainwater catchment system would not be beneficial.

The use of individual water meters is a recent requirement (since the year 2011) for building new residential developments in Rio de Janeiro. The system consisted of the inclusion of velocity-type meters, with a nominal flow rate of 2.5 m³ / h, inserted in the potable water distribution point in each unit, i.e., 32 apartments plus 1 unit corresponding to the common areas of the development (see Figure 7).

Figure 7 – Water metering diagram



Source: Adapted from CARVALHO, 2010.

It was calculated that the cost for implementing the system would be of USD 22.56 per apartment. According to monitoring carried out by similar studies (BEZERRA & OLIVEIRA, 2016; COELHO, 1999, *apud* CARVALHO, 2010), it was considered that individual metering would lead to a 30% reduction in the consumption of potable water. Taking into account the original monthly consumption of 31 m³ per apartment and the amount charged of USD 1.108068 per cubic meter (resulting in a cost of USD 34.35 per apartment), a saving of USD 9.98 per apartment was estimated. When this amount was reduced by the operating cost of USD 4.69

(relating to remote monitoring undertaken by an outsourced company), a monthly saving of USD 5.29 per apartment was obtained.

2.3. Feasibility parameters for real estate development

After presenting the sustainable solutions systems, the financial analysis was undertaken on the real estate development, by grouping the estimated revenue and expenses of the design over time to demonstrate the financial flows of the development and its results for developers. The analysis was undertaken by setting up the development's cash flow in an electronic spreadsheet, listing the items generating expenses and revenue and their respective amounts. The items were inserted over the period of existence of the development, according to a schedule made for the development, construction and sales processes. Financial indicators such as Internal Rate of Return (IRR), Margin, Potential Sales Value (PSV), Payback and Net Present Value (NVP) were used, based on calculation tools provided by the Microsoft Excel software.

The parameters used for the study were established based on market research and professional experience of the authors. It was established as a goal for the financial feasibility that the results of the conventional study (without the use of any sustainable solution) must achieve a minimum Internal Rate of Return and Margin of 20%; the other sustainable scenarios must have their sale prices adjusted to match the indicators achieved in the conventional study. For the other parameters, the following criteria were considered:

a) It was stipulated that the apartments would be sold by way of a bank mortgage loan to the purchasers, such that at the end of construction the developer would transfer the customer portfolio to a bank, thereby bringing forward a large part of the revenue. Such an operation is common in the Brazilian real estate market.

b) It was assumed that the construction would be carried out with the company's own funds, without the need to take out an external loan to finance the work.

c) With regard to the schedule, it was defined that the completion of the development would last a total of 41 months. The land being bought in the 1st month, the construction starting in the 15th month, the end of construction in the 38th month (it taking 24 months). Delivery of the properties to the buyers in the 39th month and the end of the proceeds from the transfer in the 41st month.

d) According to the project, the area for sale reached 2,960.00 m² (32 apartments with 92.5 m² each).

e) The sale price was stipulated at USD 2,125.00 per m² of private area, thereby forecasting a Total Potential Sales Value of USD 6,290,000.00.

f) For this residential product, the proportion of 30% was used for the rate of sales of units sold upon launching the development, 50% during construction and the remaining 20% during the month of delivery of the completed units.

g) The revenue stream with sales considered the following form of payment: 10% as initial deposit, 20% in instalments during the construction and 70% after the delivery of the apartments.

h) The cost of the land was pre-established as USD 1,562,500.00, adding extra costs related to the purchase, such as land transfer tax (2% on land cost), brokerage (5% on land cost) and due diligence costs (1.25% on land cost), totalling USD 128,750.00, thus resulting in an amount of USD 1,691,250.00 as the cost related to the land.

i) The equivalent built-up area was defined as 4,135.22 m².

j) The construction cost per square metre was established as USD 432.34, as per the amount disclosed by the Civil Construction Industry Trade Union for the State of Rio de Janeiro for the month of April 2017. This resulted in a construction cost for the building and gatehouse of USD 1,787,809.55. Added to this amount, there were another USD

334,839.80 relating to extra construction costs, such as for the foundations (USD 143,024.76 corresponding to 8% of the cost of the building), lifts (USD 87,500.00), general pumping and HVAC installations (USD 31,250.00), construction of the external recreational areas and other equipment (USD 73,065.04). Consequently, the total cost of the construction was USD 2,122,649.28.

k) It was assumed that the rate of disbursement of the total cost of construction during the 24 months period would correspond to 25% of expenditure in the first 8 months, 35% in the following 8 months and 40% in the final 8 months.

l) Administrative expenses of the development were included, equivalent to 5% of the overall construction cost, totalling USD 106,132.46.

m) The design-related expenses were estimated at 5% of the overall construction cost, totalling USD 106,132.46.

n) The expenses due to construction management were equivalent to 5% of the overall construction cost, totalling USD 106,132.46.

o) The expenses due to promotion and publicity were equivalent to 2.5% of the Total Potential Sales Value, totalling USD 188,700.00.

p) The expenses due to the payment of taxes were equivalent to 4% of the Total Potential Sales Value, totalling USD 251,600.00.

q) The expenses due to sales commission were equivalent to 4.5% of the Total Potential Sales Value, totalling USD 283.050.00.

Having defined these parameters, financial feasibility studies were carried out for the following criteria: (i) development without the use of any sustainable solution system, in the so-called conventional scenario; (ii) development that makes use of solar power, by way of a system of solar panels; (iii) development that uses a greywater reuse system; (iv) development that possesses a rainwater catchment system; (v) development that makes use of individual water meters; (vi) development that makes use of all the above systems.

3. RESULTS AND DISCUSSION

As mentioned in the introduction of this work, the analyses were carried out focusing on two main stakeholders: the real estate developers and the buyers.

3.1. Data for real estate developers

For the conventional scenario (without the use of any sustainable solution systems), all the parameters discussed in Section 2.3 were used, and the cash flow of the project was set up. The financial study for the real estate development demonstrated an Internal Rate of Return of 20.05%. The Margin was calculated based on the Profit (USD 1,402,357.33) on Revenue (USD 6,290,000.00), resulting in a percentage of 22.30% for the development. The ratio of Revenue (USD 6,290,000.00) to Expenses (USD 4,887,642.67) provided a Coverage ratio of 1.29. Payback would be achieved in the 40th month, with the maximum cash flow exposure of USD 3,089,710.41 occurring in the 38th month. The NPV amounts were calculated for the discount rates of 12%, 16% and 18% and corresponded respectively to USD 420,905.65, USD 193,802.78 and USD 93,972,66.

In order to compare the other scenarios, it was established that the IRR and Margin indices found in the study of the conventional scenario should serve as a basis for the following simulations. For this reason, the increase in cost of construction caused by the inclusion of sustainable solutions systems was compensated in each scenario by the increase in value of the square meter sold, seeking to attain an IRR of 20.05% and a Margin of 22.30%.

For the second scenario, corresponding to the development making use of solar power, there was a need to increase the sales price by USD 26.88 per square meter, going from USD 2,125.00 to USD 2,151.88 (corresponding to an increase of 1.26%). This was due to the extra amount of USD 44,960.63 in construction costs, related to the cost of implementing the system. Consequently, the result of Internal Rate of Return of this new scenario reached 20.16%, although the same 22.30% Margin was maintained. The Profit increased to USD 1,420,379.59 and Revenue rose to USD 6,369,550.00. The ratio of Revenue (USD 6,369,550.00) to Expenses (USD 4,949,170.41) provided a Coverage ratio of 1.29, the same figure achieved for the conventional scenario. Payback was achieved in the 40th month, with the maximum cash flow exposure of USD 3,113,278.16, also occurring in the 38th month.
For the third scenario, featuring a greywater reuse system, the amount of USD 2,7576,87 was added. The need to increase the sale price by USD 16.56 per square metre was determined, going from USD 2,125.00 to USD 2,141.56 (corresponding to an increase of 0.78%). As a result, the IRR was equal to 20.12% and the Margin equal to 20.30%, in order to match this ratio in the conventional scenario. Profit was calculated as USD 1,413,617.41, Revenue as USD 6,339,025.00 and Expenses as USD 4,925,407.59. The Coverage ratio was 1.29, with a maximum cash flow exposure of USD 3,113,278.16, again occurring in the 38th month. The calculations showed that the Payback for this simulation was achieved in the 40th month.
The fourth scenario involving the implementation of the rainwater catchment system featured an increase of USD 5,096.60 in the total cost of construction for installing the system. In order for the Margin under this scenario to match that of the conventional scenario, it was necessary to increase the sales price per square metre by USD 2.81, going from USD 2,125.00 to USD 2,127.81 (corresponding to an increase of 0.15%). The IRR was calculated as 20.07% and the Margin as 22.30%. The calculated Profit was USD 1,404,606.04, with Revenue of USD 6,299,250.00 and Expenses of USD 4,894,643.96. The Coverage ratio was calculated as 1.29, with Payback being achieved in the 40th month. It was determined that maximum cash flow exposure of USD 3,094,034.77 would also occur in the 38th month.
The fifth scenario involving the use of individual water meters required an increase of USD 721.88 in the cost of construction. In order for the Margin ratio in this scenario to match the conventional scenario, there was the need to increase the sale price per square metre by USD 0.63, going from USD 2,125.00 in the conventional scenario to USD 2,125.63 in the scenario with the use of individual water meters. Consequently, sale price and revenue were increased by 0.03%, with Revenue totalling USD 6,291,850.00. Expenses were calculated as USD 4,888,696.40 and the resulting Profit was USD 1,403,153.60, featuring the IRR equal to 20.06% and a Margin equal to 22.30%. The Coverage Ratio was calculated as 1.29 and Payback achieved in the 40th month of the development, with maximum cash flow exposure of USD 3,090,233.72 occurring in the 38th month.
The sixth and last scenario was set up with the inclusion of all sustainable systems in the development. The total cost of all solutions gave rise to an additional increase of USD 78.355,97 to the overall construction cost. To match the Margin ratio of 22.30% found in the conventional scenario, it was necessary to increase the sale price per square meter by USD 46.88, going from USD 2,125.00 in the conventional scenario to USD 2,171.88. The Total Potential Sales Value reached USD 6,428,750.00, giving rise to a 2.21% increase compared to the conventional scenario. This design resulted in an Internal Rate of Return of 20.25%. The Margin was calculated based on the Profit (USD 1,433,866.38) on Revenue (USD 6,428,750.00), resulting in a percentage of 22.30% for the development. The ratio of Revenue (USD 6,428,750.00) to Expenses (USD 4,994,883.62) provided a Coverage ratio calculated as 1.29. Payback would be achieved in the 40th month, with maximum cash flow exposure of USD 3,156,765.55, occurring in the 38th month. The summary of these results can be seen in Table 4.

Table 4 – Results for real estate developers

Index	Conventional Scenario	Solar Power Scenario	Greywater Reuse Scenario	Rainwater Catchment Scenario	Individual Water Meters Scenario	All Solutions Scenario
IRR	20.05%	20.16%	20.12%	20.07%	20.06%	20.25%
Margin	22.30%	22.30%	22.30%	22.30%	22.30%	22.30%
Sales price increase	-	1.26%	0.78%	0.15%	0.03%	2.21%
PSV	USD 6,290,000	USD 6,369,550	USD 6,339,025	USD 6,299,250	USD 6,291,850	USD 6,428,750
Expenses	USD 4,887,643	USD 4,949,170	USD 4,925,408	USD 4,894,644	USD 4,888,696	USD 4,994,884
Profit	USD 1,402,357	USD 1,420,380	USD 1,413,617	USD 1,404,606	USD 1,403,154	USD 1,433,866
Maximum exposure	USD 3,089,710	USD 3,128,198	USD 3,113,278	USD 3,094,035	USD 3,090,234	USD 3,156,766
Coverage	1.29	1.29	1.29	1.29	1.29	1.29
Payback [month]	40	40	40	40	40	40
NPV 12%	USD 420,906	USD 429,736	USD 426,468	USD 422,052	USD 421,406	USD 436,367
NPV 16%	USD 193,803	USD 200,559	USD 198,078	USD 194,700	USD 194,234	USD 205,641
NPV 18%	USD 93,973	USD 99,825	USD 97,687	USD 947,573	USD 94,373	USD 104,233

Source: The authors

Based on the analysis of the six scenarios, the feasibility studies confirmed the need to increase the sale price of the properties to match the Margin ratio (22.30%) found in the conventional scenario. The use of photovoltaic power ended up being the most costly system to be implemented, leading to the need for the developer to invest USD 38,487.26 more. However, it produced the best Result (Profit) out of the four systems separately. At the same time, the use of individual water meters resulted in the need for the lowest increase in investment, of USD 523.31. However, the increase in the Result was the least significant.

A general framework was set up in which all simulations proved to be feasible for the developer, based on the increases in revenues generated by the respective increment in the sale price of the properties. However, the effective financial and commercial success of the scenarios could only be validated through the consumer's acceptance of the increased sales price.

In this regard, it was important to mention again the research conducted by the Sensus Institute (2014), which shows that on average Brazilian consumers with income over 20 times the minimum monthly wage accepted a maximum increase of USD 2,031.25 in the price of new properties for the inclusion of solar energy and water saving devices. Thus, this research indicated the need to demonstrate to the buyer the performance and economic data during the operating cycle of the building, in order to justify the increase and analyse the financial attractiveness for both stakeholders.

3.2. Data for buying customers

In order to demonstrate to buyers the financial gains resulting from the sustainable solutions systems, the results were presented at the Net Present Value for the periods of 20 and 60 years of operation, as well as the discounted Payback periods of each solution. For the calculation of these two indicators, a discount rate was applied to bring the cash flow to the present value. This corresponded to the 11.25% per year basic interest rate defined by the Brazilian government, effective in April 2017 (BRAZIL, 2017). Concurrently, a monetary adjustment index of 3.37% p.y. was applied to operating costs, which corresponded to the annual inflation recorded in the last 12 months for the Brazilian economy. In the same way, corrections were applied to energy and water supply prices. These increases were respectively 9.78% p.y. and 12.079% p.y., due to the history of price increases applied by the supplier companies.

Among the four systems, the use of individualized hydrometers resulted in the lower increase to the purchase price of the apartment, in the amount of USD 57.81. It is noted that this cost is differed from the previously calculated amount of USD 22.56 for this system inclusion. The reason for this is that indirect expenses (development costs, management, projects, advertising and taxes) increased along with the increase in the construction cost and PSV, leading the developer to raise the sale value. This logic was repeated in all other sustainable scenarios. Considering the initial investment of USD 57.81, plus the reinvestment of USD 22.56 (to exchange the meters every 10 years) and the monthly savings of USD 5.29, the payback was achieved after 13 months (1.1 years), being the most immediate return among all the studied systems. The expected NPV was USD 1,670.45 after 20 years and USD 7,984.27 after 60 years.

The photovoltaic technology presented the largest increase in the cost of the apartment, of USD 2,485.94. However, the monthly savings of USD 29.65 led to a positive balance of USD 2,868.68 at the end of 20 years and USD 7,031.53 at the end of 60 years of operation, considering the renewal of the system every 20 years. In this case, the payback was reached after 8.2 years.

Regarding greywater reuse, the increase in the cost of the apartment was calculated as USD 1,532.03. Due to a low saving of USD 2.18 per month generated by the system, payback was only achieved at the end of 29.6 years. This period was considered excessively long. At the end of 20 years, the expected NPV was negative, in the amount of USD 645.50. After 60 years, the positive balance was USD 2,887.24. Consequently, its inclusion was not very appealing in this specific case.

Different from the other technologies, the rainwater catchment system began operations with negative results of minus USD 1.13 per month. This occurred due to the operating costs being higher than the achieved consumption saving. Despite inverting the negative operating result after the 13th year, the system did not manage to produce a profit at the end of the 20 and 60 years of analysis, generating negative balances of USD 1,581.35 and USD 1,184.03, respectively. This made its use unviable.

Considering the scenario of making use of all sustainable solutions, the implementation of sustainable systems led to a rise of USD 4,335.94 in the final price of the residential unit. The combined monthly savings of USD 35.99 made this investment reach its payback after 11.2 years. It’s worth nothing that after 20 years of operations, the created saving gives rise to a positive result for the present value of USD 3,217.29 per apartment. Undertaking this analysis at the end of a period of 60 years, profit rises to USD 17,109.98, including the costs of two replacements of the photovoltaic system (due to the estimated lifespan of 20 years) and five replacements of the individual water meters (due to the equipment's useful lifespan of 10 years). As shown in the system descriptions, it was stipulated that the greywater reuse and water catchment systems had a useful lifespan of 60 years, without the need to replace the equipment before the end of this period.

4. CONCLUSIONS

These results made the use of two of the four solutions for this development financially attractive: photovoltaic power and individual water meters. Removing the greywater reuse and water catchment systems from the comparison, the results became even more interesting for both the buying customer and the developer. This simulation demonstrated an increase of Potential Sales Value by 1.28% for the developer, with costumer payback being achieved at the end of six years and eight months. The summary of the main results is presented in Table 5.

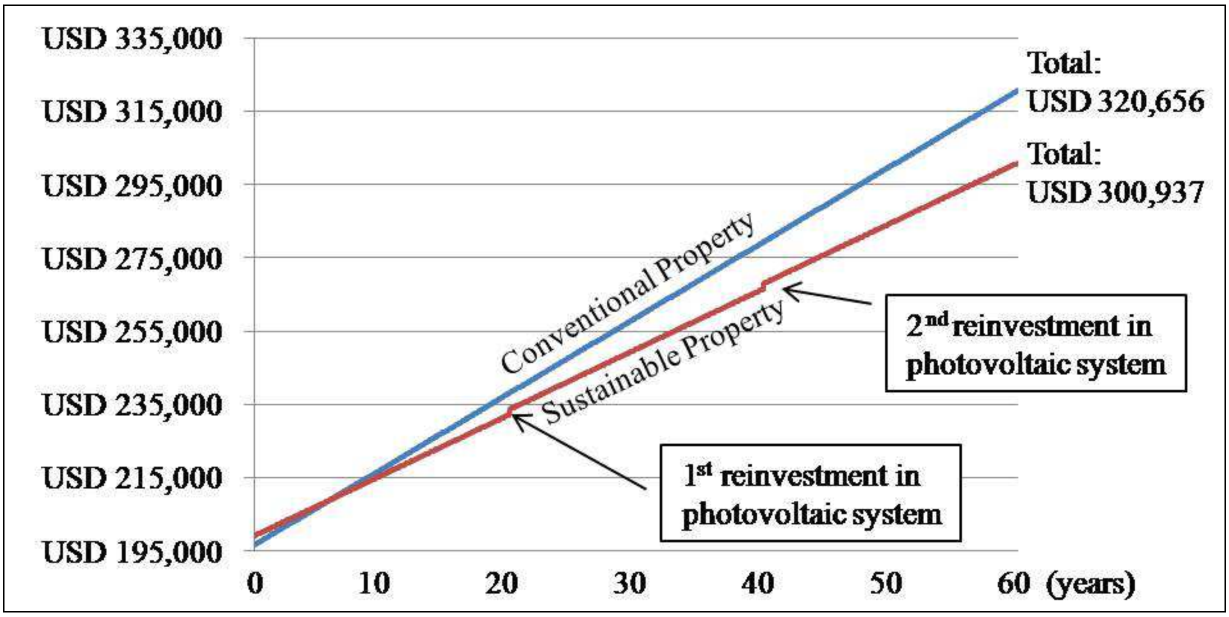
Table 5 - ***Summary of the main results***

Stakeholders Group	**Index**	**Single use solutions**					**Mixed solutions**	
		Conventional Scenario	**Solar Power Scenario**	**Greywater Reuse Scenario**	**Rainwater Catchment Scenario**	**Individual Water Meters Scenario**	**All Solutions Scenario**	**Solar Power & Individual meters Scenario**
Real Estate Developers Data	**IRR**	20.05%	20.16%	20.12%	20.07%	20.06%	20.25%	20.16%
	Margin	22.30%	22.30%	22.30%	22.30%	22.30%	22.30%	22.30%
	PSV	USD 6,290,000	USD 6,369,550	USD 6,339,025	USD 6,299,250	USD 6,291,850	USD 6,428,750	USD 6,370,475
Consumers Data	**Payback [years]**	-	8.2	29.6	No Payback	1.1	11.2	6.7
	Result After 20 Years	-	USD 2,868	-USD 645	-USD 1581	USD 1,670	USD 3,217	USD 4,568
	Result After 60 Years	-	USD 7,032	USD 2,887	-USD 1,184	USD 7,984	USD 17,109	USD 15,044
Financial Interest for Both Groups		-	Yes	No	No	Yes	Yes	Yes

Source: The authors

Based on the data obtained from the analysis of the overall building costs, it was possible to compare the overall cost of the conventional building as opposed to the sustainable construction over the development's 60-year lifespan (disregarding the present value). Taking as a basis a sustainable development making use of the solutions of photovoltaic solar power generation and use of individual meters *versus* the conventional development, it was noted that, although there would be a higher initial cost in acquiring the sustainable property by 1.28%, there would be a reduction in the accumulated overall cost over time, of 6.14% at the end of the cycle of 60 years, even when considering the need for reinvestment in the acquisition of water meters every ten years and the need for reinvestment in the photovoltaic system every 20 years. The final result over 60 years was USD 19,690.67 in net savings per apartment, making this scenario attractive for the purchaser of a sustainable property (see Figure 8). It was also observed that this data could be used positively to evaluate the property in the event of resale or leasing.

Figure 8- Comparison between the overall costs accumulated over 60 years per apartment



Source: The authors

Among the final considerations of this paper, it was observed that the subject of sustainability is being studied by academics, but is still infrequently applied by developers in the Brazilian real estate market. However, it was shown that the presentation of performance and consumption savings data is extremely useful for investors, owners and lessees of properties and is a driving force for consumers to purchase and use properties that are more efficient. There is significant space for growth in sustainable residential real estate and respective financial viability depends on the exploration of savings generation during operations compared against the increase in the sale price. This paper intended to contribute to the decision-making process on investments in sustainability among developers (with a special focus on the city of Rio de Janeiro), as well as to bring the discussion about optimizing properties to prominence among consumers.

5. REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. *NBR 12211*: Estudos de concepção de sistemas públicos de abastecimento de água. Rio de Janeiro, 1992. 14p.

_______. *NBR 12721*: Avaliação de custos unitários de construção para incorporação imobiliária e outras disposições para condomínios edilícios — Procedimento. Rio de Janeiro, 2006. 94p.

BARRETO, D. *Perfil do consumo residencial e usos finais da água.* Ambiente Construído, volume 8, n. 2. 23-40 (June 2008). Porto Alegre, 2008. Available from: <http://www.seer.ufrgs.br/index.php/ambienteconstruido/article/view/5358/3280>.

BEZERRA, M. M.; OLIVEIRA, A. J. *Medição individualizada de água: momento e analises de exemplos no Rio de Janeiro.* Paper presented at Encontro da Associação Nacional de Pesquisa e Pós-Graduação em Arquitetura e Urbanismo, 4., Porto Alegre (2016). Porto Alegre: ANPARQ, 2016. Available from: <http://www.anparq.org.br/dvd-enanparq-4/SESSAO%2004/S04-02-BEZERRA,%20M;% 20OLIVEIRA,%20A.pdf>.

BRASIL. Banco Central do Brasil. *Histórico das Taxas de Juros.* Brasília, DF, 2017. Available from: <https://www.bcb.gov.br/Pec/Copom/Port/taxaSelic.asp>.

CABRAL, B. F. et. al. *Impactos sócio-ambientais dos lava-jatos da cidade de Palmas – TO.* Palmas: Universidade Católica do Tocantins, 2009. 13p.Available from: <http://www.catolica-to.edu.br/portal/portal/downloads/docs_gestaoambiental/projetos2009-1/3-periodo/Impactos_socioambientais_dos_lava-jatos_da_cidade_de_palmas-to.pdf>.

CARVALHO, W. F. *Medição Individualizada de Água em Apartamentos.* Belo Horizonte: Universidade Federal de Minas Gerais, 2010. p. 56. Monografia (Especialização em Construção Civil). Available from: <http://pos.demc.ufmg.br/novocecc/trabalhos/pg2/51.pdf>.

GONÇALVES, R. F. (Coord.). *Conservação de água e energia em sistemas prediais e públicos de abastecimento de água.* In: Programa de Pesquisa em Saneamento Básico – Edital 05. Vitória: ABES, 2009. Available from: <https://www.finep.gov.br/images/apoio-e-financiamento/historico-de-programas/prosab/prosab5_tema_5.pdf>.

GOODMAN, J. *Determinants of Operating Costs of Multifamily Rental Housing.* Cambridge: Working Papers – Joint Center for Housing Studies, Harvard University. 2004. 25p. Available from: <http://www.jchs.harvard.edu/sites/jchs.har-vard.edu/files/w04-7.pdf>.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICAS. *Pesquisas. Censo. Sinopse. Rio de Janeiro. População Residente.* Rio de Janeiro, 2010. Available from: <https://cidades.ibge.gov.br/brasil/rj/rio-de-janeiro/pesquisa/23/25207?tipo =ranking>.

INSTITUTO SENSUS. *Pesquisa Nacional da Câmara Brasileira da Indústria da Construção – A Inovação na Construção Civil no Brasil sob a Ótica do Consumidor.* CBIC, 2014. 35p. Available from: <http://www.cbic.org.br/sites/default/files/CBIC_Web.pdf>.

ROGERS, R.; GUMUCHDJIAN, P. *Cities for a small planet.* London: Faber and Faber, 1997. 180p.

SINDICATO DA INDÚSTRIA DA CONSTRUÇÃO CIVIL NO ESTADO DO RIO DE JANEIRO. *Custos Unitários da Construção – Abril 2017*. Rio de Janeiro, 2017. Available from: <http://www.sinduscon-rio.com.br/pdfs2017/cub.pdf>.

WEISE, A. D.; SCHULTZ, C. A.; TRIERWEILLER, A. C. *Custos Imobiliários: a Aplicação dos Conceitos do Custo de Ciclo de Vida.* Paper presented at Congresso UFSC de controladoria e finanças, Florianópolis (2008). Organized by Ernesto Fernando R. Vicente. Florianópolis: Departamento de Ciências Contábeis; Universidade Federal de Santa Catarina, 2008. Available from: <dvl.ccn.ufsc.br/congresso/anais/2CCF/20080810162708.pdf>.