Extended Abstract


The increase in the global population and the ever-increasing development of cities have given rise to various challenges to be overcome in environmental, social, cultural and economic terms. This situation makes it important to encourage the use of new technological solutions to build more sustainable cities and the real estate market has an important role in this process, because the incorporation of sustainable practices into buildings is decided upon during the design of real estate developments.

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. On the other hand, within the real estate market in the city of Rio de Janeiro, it is unusual to find multi-family housing developments 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 construction. 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, since the probable increase in the cost of initial construction still does not lead to visible, immediate gains for real estate developers. In addition, consumers do not have clarity on the gains tied to acquiring sustainable buildings. Information is lacking on the 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 adopt 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 by way of studies confirming their profitability and financial returns for both interested parties. In this way, this paper has the objective of demonstrating the financial results from using four sustainable
building systems in a hypothetical residential development located in the city of Rio de Janeiro, by evaluating details of interest to developers, such as development costs, the need for adjustment to 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. A secondary objective consists of the presentation of 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.

As such, this paper focuses on four so-called sustainable building systems, chosen due to the fact that they were the four most valued items in research undertaken in 2014 by a Brazilian research entity, the Sensus Institute. These systems are:

a. Electrical power generation by way of a photovoltaic solar system;
b. Recycling and re-use of greywater.
c. Rainwater catchment
d. Individual water metering

In order to study the economic impact from the use of each of the sustainable technologies in the development, scenarios were created for evaluation from two perspectives: that of developers and that of buying customers.

The method of the dynamic feasibility study was selected for the development process, without forecasting inflation, considering that possible adjustments for inflation are offset both upon the disbursement of expenses and upon receiving revenue. In this way, the cash flows of each scenario were forecast, resulting in the financial indicators to be compared.

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.

To piece together the hypothetical development, a piece of land situated at Rua Araguaia, Freguesia neighbourhood, located in the West Zone of the City of Rio de Janeiro, was chosen. The development follows 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 due to being that normally used in real estate developments throughout Brazil. The design consists of a multi-family building with a garage, pilotis and eight typical floors, with normal finishing standards, featuring four units per floor, as
well as a common recreational area for the condominium. With respect to the
apartments, each unit measures 92.5 m², containing three bedrooms, one being
en suite, a living room, a dining room, a main bathroom, a kitchen, a utility area
with a bathroom and veranda. The sum of the built-up areas adds up to a gross
floor area of 6,254.73 m². The standard also includes the fact of each building
environment involving higher or lower costs for respective construction, based on
the respective finishing features and complexity of construction. As such, the
gross floor areas are weighted based on coefficients of equivalence, and result in
an equivalent built-up area 4,241.22 m². The target consumer for this
development is families with an income of more than 20 minimum monthly
salaries, and this paper stipulates 162 residents and employees spread
throughout the 32 housing units.

Energy and water consumption in the building was estimated, in order to
determine the costs from these items for operating the development. With
reference to energy consumption, the items used inside the building, such as
lighting and electrical equipment, were identified. Based on the period of
operation and the capacities of this equipment, the study calculated monthly
consumption of around 523.33kWh per apartment. With respect to water
consumption, daily consumption of 200 Litres per capital was stipulated, resulting
in monthly consumption per apartment of 1,012.5 Litres. Sewage production is
also an important detail for evaluating the possibility of reusing these effluents for
non-potable purposes. As such, based on the qualitative distribution of water
consumption, it is possible to determine the building's production of greywater,
originating from effluents from showers, lavatories, washing machines, tanks and
floor drain in wet areas. The study demonstrated a monthly production estimate
of 458.7 Litres of greywater per apartment. Following the presentation of the
buildings consumption data, the four studied sustainable systems were
described.

The photovoltaic power generation system is defined as an on-grid system,
the installed capacity of which is 30 kWp, limited as a result of the area available
on the building's roof. It produces approximately 3,690 kWh for the development,
at a setup cost of BRL 143,875.00 and generates a monthly net saving of 94.89
per apartment along the twenty-year lifespan.

The greywater reuse system was adopted based on current legislation in
the city of Rio de Janeiro, although in Brazil there are still no specific technical
standards on treatment and sizing. Its size was determined based on the required
volume of non-potable water for watering gardens, washing cars and cleaning
floors, giving rise to the need to treat 5,427 Litres daily. The cost of setting up the system was calculated based on the additional materials and labour for its construction, resulting in BRL 88,245.97. It was determined that the consumption reduction leads to a saving in the monthly bill of BRL 17.73 per apartment, at an operating cost of BRL 10.74 monthly per apartment, leading to a net monthly saving of BRL 6.99 per apartment.

The rainwater catchment system has the capacity to reduce the development's monthly consumption of potable water by 22 m³, partially covering the demand for use in watering gardens and washing cars. The total cost of implementing the system was calculated as BRL 16,309.13. It was discovered that based on 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, there being the need to supplement the demand with potable water from the local water supply company. As such, the monthly net saving per apartment was calculated as BRL 2.22, the monthly operating cost being BRL 5.85 per apartment, resulting in a negative monthly result of BRL 3.63 per apartment. These results demonstrated that, for this development, initially this technology 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. It was calculated that the cost for implementing the system would be BRL 72.19 per apartment and it was considered that individual metering would lead to a 30% reduction in the consumption of potable water (based on monitoring from similar studies), resulting in a saving of BRL 31.92 per apartment. The monthly operating cost was calculated as BRL 15.00 relating to remote monitoring undertaken by an outsourced company. The result would be a monthly saving of BRL 16.92 per apartment.

After presenting the solutions, financial analyses were 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 investors. The analysis in itself was undertaken by setting up the development's cash flow in an electronic spreadsheet, listing the items generating expenses and revenue, with the respective amounts. The items were inserted over the period of existence of the development, at pre-established milestones. The spreadsheet calculated and displayed the financial indicators and resulting time periods, which serve as the grounds for making decisions on business undertakings, including the option of whether or not to invest in sustainable aspects in the development.
The parameters used for the studies were established based on market research and the author's professional experience. It was determined 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 details were stipulated:

a) The units were sold by way of a bank mortgage loan to the purchasers, such that at the end of construction the developer transferred the customer portfolio to a bank, thereby bringing forward a large part of the revenue. Such an operation is common on the Brazilian real estate market.

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

c) The completion of the development lasted a total of 41 months, the land being bought in the 1st month, the construction started 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 29th month and the end of the proceeds from the transfer in the 41st months.

d) The cost of the land was pre-established as BRL 5,000,000.00, with extra costs relating to the purchase, such as land transfer tax, brokerage and due diligence costs, totalling BRL 412,000.00.

e) The construction area was 4,135.22 m² and the area for sale was 2,960.00 m².

f) The basic unit cost of construction was BRL 1,383.48 per square metre, 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 BRL 5,720,990.55. Added to this amount, there was another BRL 1,071,487.35 relating to extra construction costs, such as for the foundations, lifts, construction of the external recreational areas and other equipment. As such, the total cost of the construction was BRL 6,792,477.71.

g) The rate of disbursement of the total cost of construction during the 24 months of construction corresponded to 25% expenditure in the first eight months, 35% in the following 8 months and 40% in the final 8 months.
h) The administrative expenses of the development were equivalent to 5% of the overall construction cost.
i) The design-related expenses were equivalent to 5% of the overall construction cost.
j) The expenses due to construction management were equivalent to 5% of the overall construction cost.
k) The expenses due to promotion and publicity were equivalent to 5% of the Total Potential Sales Value.
l) The expenses due to the payment of taxes were equivalent to 4% of the Total Potential Sales Value.
m) The expenses due to sales commission were equivalent to 4.5% of the Total Potential Sales Value.
n) The sale price was stipulated at BRL 6,800.00 per m² of private area, thereby forecasting an Overall Sales Volume of BRL 20,128,000.00.
o) For this residential product, as a hypothesis, the proportion of 30% was used for the rate of sales as to units sold upon launching the development, 50% during construction and the remaining 20% during the month of delivery of the completed units.
p) The form of payment of the residential units was set out in three sales tables, with one for the time of launch, one for mid-construction and one for the time of delivery of the keys, as per Table 5.11.

Having defined these parameters, financial feasibility studies were carried out for the following criteria:

a. development without the use of any sustainable solution, in the so-called conventional scenario.
b. development that makes use of solar power, by way of a system of solar panels.
c. development that possesses a greywater re-use system.
d. development that possesses a rainwater catchment system.
e. development that makes use of individual water meters.
f. development that makes use of all the mentioned systems.

For the conventional scenario, the financial studies for the real estate development demonstrated an Internal Rate of Return of 20.05%. The Margin was calculated based on the Profit (BRL 4,487,543.46) on Revenue (BRL 20,128,000.00), resulting in a percentage of 22.30% for the development. The ratio of Revenue (BRL 20,128,000.00) to Expenses (BRL 15,640,456.54)
provided a Coverage ratio of 1.29. Payback would be achieved in the 40th month, with the maximum cash flow exposure occurring in the 38th month, in the amount of BRL 9,887,073.31. The NPV amounts were calculated for the discount rates of 12%, 16% and 18% and corresponded respectively to BRL 1,346,898.07, BRL 620,168.89 and BRL 300,712.50.

For the second scenario, corresponding to the development making use of solar power, an extra amount of BRL 143,874.00 was added relating to the system implementation cost. To achieve the IRR and Margin ratios of the conventional scenarios, it was determined that the sale price would have to be increased by BRL 86.00 per square meter, going from BRL 6,800.00 to BRL 6,886.00. This would correspond to a 1.26% increase in the sale price. As such, the result of Internal Rate of Return of this new scenario would reach 20.16%, although the same 22.30% Margin would be maintained. The Profit was BRL 4,545,214.69 and Revenue rose to BRL 20,382,560.00. The ratio of Revenue (BRL 20,382,560.00) to Expenses (BRL 15,837,345.31) provided a Coverage ratio of 1.29, the same figure achieved for the conventional scenario. Payback would be achieved in the 40th month, with the maximum cash flow exposure also occurring in the 38th month, in the amount of BRL 9,962,490.11.

For the third scenario, featuring a greywater re-use system, the amount of BRL 88,245.97 was added. The need to increase the sale price by BRL 53.00 per square metre was determined, in order to match the Margin ratio in the conventional scenario. As such, as a result, IRR would be equal to 20.12% and the Margin equal to 20.30%. Profit was calculated as BRL 4,523,575.71, Revenue as BRL 20,284,880.00 and Expenses as 15,761,304.29. The Coverage ratio was 1.29, and maximum cash flow exposure would occur in the 38th month, in the amount of BRL 9,962,490.11. Payback of the development would be achieved in the 40th month.

The four scenario involving the implementation of the rainwater catchment system featured an increase of BRL 16,309.13 in the total cost of construction for installing the system and gave rise to the need to increase the sales price per square metre by BRL 9.00, in order for the Margin under this scenario to match that of the conventional scenario. In this way, IRR was calculated as 20.07% and the Margin as 22.30%. The calculated Profit was BRL 4,494,739.33, with Revenue of BRL 20,157,600.00 and Expenses of 15,662,860.67. The Coverage ratio was calculated as 1.29, with Payback being achieved in the 40th month. It was determined that maximum cash flow exposure would occur in the 38th month, in the amount of BRL 9,900,911.26.
The fifth scenario involving the use of individual water meters features an increase of BRL 2,310.00 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 BRL 2.00, going from BRL 6,800.00 in the conventional scenario to BRL 6,802.00 in the scenario with the use of individual water meters. As such, the sale price and revenue would increase by 0.03%, with Revenue totalling BRL 20,133,920.00. Expenses were calculated as BRL 15,643,828.49 and the resulting Profit was 4,490,091.51, featuring the IRR equal to 20.06% and a Margin equal to 22.30%. The Coverage Ratio was calculated as 1.29 and Payback would occur in the 40th month of the development, with maximum cash flow exposure of BRL 9,888,747.89 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 BRL 250,739.10 to the overall construction cost. To match the Margin ratio of 22.30% found in the conventional scenario, this new scenario would require a BRL 150.00 increase in the sale price per square meter, going from BRL 6,800.00 in the conventional scenario to BRL 6,950.00. In this way, the Total Potential Sales Value would be BRL 20,572,000.00, giving rise to a 2.21% increase compared to the conventional scenario. This design would result in an Internal Rate of Return of 20.25%. The Margin was calculated based on the Profit (BRL 4,588,372.41) on Revenue (BRL 20,572,000.00), resulting in a percentage of 22.30% for the development. The ratio of Revenue (BRL 20,572,000.00) to Expenses (BRL 15,983,627.59) provided a Coverage ratio calculated as 1.29. Payback would be achieved in the 40th month, with maximum cash flow exposure being equal to BRL 10,101,649.75, occurring in the 38th month.

With the real estate development being viewed as a market product and its sale featuring a producer and a consumer, it is considered that the results of the studies must be evaluated based on two aspects: a) from the perspective of the real estate developer, the producer; b) from the perspective of the buying customer, the consumer.

With respect to the details of interest to the developer, the feasibility studies demonstrated that in all scenarios there is the need to increase the sale price of the properties to match the Margin ratio (22.30%). The use of photovoltaic power ended up being the most costly system to be implemented, giving rise to the need for the developer to invest BRL 123,159.23 more, however it produced the best Result (Profit) out of the four systems separately. In this way, the use of
individual water meters resulted in the need for the lowest increase in investment, of BRL 1,674.58, however the increase in the Result was the least significant.

In the scenario with the use of all sustainable solutions, there was the need to increase the sale price per square metre by BRL 150.00. The same 22.30% was maintained relating to Margin and the Internal Rate of Return experienced a slight increase, of 0.20%. The investment requirement rose by BRL 214,576.44, this increase being equivalent to 2.17% with respect to the investment in the conventional scenario. With respect to Expenses, it was perceived that the investment increase was not the same as the extra cost of BRL 250,739.10 relating to all systems. This was due to the fact that the Development, Construction Management, Designs and Decoration/Landscaping costs are linked to the overall construction cost. In this way, the costs of Promotion and Publicity, Taxes and Sales Commissions increase based on the sales price of units.

The comparison of Revenue in the conventional scenario versus the scenario with the use of all solutions demonstrates the need to increase the sale price per square meter by BRL 150.00, raising the Total Potential Sales Value from BRL 20,128,000.00 to BRL 20,572,000.00. This results in an increase of BRL 444,000.00 (equal to 2.21%). As a consequence, this leads to a rise of BRL 13,875.00 in the final price of the residential unit. Taking into consideration the research on Consumers' Willingness to Pay, the increase in the sale price is above the average increase in the property price accepted by the public with an income above 20 minimum monthly salaries. However, the acceptance of these increases by customers may be achieved if justified by the presentation of building performance data.

With respect to the data of interest to customers, it is important to demonstrate to buyers the financial gains resulting from the saving caused by the reduction in power and water consumption during the development's operations, also given discounted Payback periods for the investments made in the purchase of a sustainable property, when compared with a so-called conventional property (see Table 6.3 of the complete paper).

The use of individual water meters ended up being the system with the quickest payback of all, of 13 months (1.1 years), also with the lowest investment per unit. Photovoltaic technology featured payback at the end of 8.2 years, giving rise to a positive balance of BRL 22,500.90 at the end of 60 years of operations. On the other hand, the rainwater catchment system began operations with negative results (due to the operating costs being higher than the achieved
consumption saving) and despite the negative operating result inverting after the 13th year, the system did not manage to produce a profit at the end of the 60 years of analysis, making its use unviable. As to greywater re-use, there was also low profitability and *payback* was only achieved at the end of 29.6 years. This period is considered long and results from the high cost of implementing the system and the low demand for non-potable water. As such, its inclusion is not very appealing in this specific case.

With respect to the scenario of making use of all sustainable solutions, the implementation of sustainable systems has *payback* set at 11.2 years. The fact stands out that after 20 years of operations, the created saving gives rise to a positive result for the present value of BRL 10,295.34 per apartment, excluding the investment in equipment replacement. Undertaking this analysis at the end of a period of 60 years, profit rises to BRL 54,751.95, 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). It is stipulated that the greywater re-use and water catchment systems have a useful lifespan of 60 years, without the need to replace the equipment before this period ends.

These results make use of two of the four solutions for this development interesting. Removing the greywater re-use and water catchment systems from the comparison, the results become even more interesting in the medium-to-long term for the buyer, since *payback* is achieved at the end of six years and eight months. The summary of the main results can be seen in Table T.1.

**Table T.1: Summary of the main results**

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Index</th>
<th>Conventional Scenario</th>
<th>Solar Power Scenario</th>
<th>Greywater Re-use Scenario</th>
<th>Rainwater Cachement Scenario</th>
<th>Individual Water Meters Scenario</th>
<th>All Solutions Scenario</th>
<th>Only Solar Energy &amp; Individual Hydrometers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Estate</td>
<td>IRR</td>
<td>20.05%</td>
<td>20.16%</td>
<td>20.12%</td>
<td>20.07%</td>
<td>20.06%</td>
<td>20.25%</td>
<td>22.30%</td>
</tr>
<tr>
<td>Data</td>
<td>PSV</td>
<td>R$ 20,128.00</td>
<td>R$ 20,382.560</td>
<td>R$ 20,284.880</td>
<td>R$ 20,157.600</td>
<td>R$ 20,133.920</td>
<td>R$ 20,572,000</td>
<td>-</td>
</tr>
<tr>
<td>Customers</td>
<td>Discounted Payback</td>
<td>-</td>
<td>8.2</td>
<td>29.6</td>
<td>No Payback</td>
<td>1.1</td>
<td>11.2</td>
<td>6.67</td>
</tr>
<tr>
<td>Data</td>
<td>Discounted Result After 20 Years</td>
<td>-</td>
<td>R$ 8.180</td>
<td>-R$ 2.086</td>
<td>-R$ 5.060</td>
<td>R$ 5.345</td>
<td>R$ 10.295</td>
<td>R$ 14.618</td>
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</tbody>
</table>

Based on the data obtained from the analysis of the overall building costs, it is possible to compare the overall cost of the conventional building versus 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 is noted that, although there would be a higher initial cost in acquiring the sustainable property by 1.28%, there would a reduction in the accumulated overall cost over time, of 6.14% at the end of the cycle of 60 years, even considering the need for re-investment in the acquisition of water meters every ten years and the need for re-investment in the photovoltaic system every 20 years. The final result over 60 years is BRL 63,010.14 in net savings per apartment, making this scenario attractive for the purchaser of a sustainable property (see Graph G.1). It is also observed that this data can also be used positively to evaluate the property in the event of resale or even leasing.

![Graph G.1: Comparison between the overall costs accumulated over 60 years per apartment](image)

Among the final considerations of this paper, we observe that the subject of sustainability is being studied by academics, but is still infrequently applied by developers in the Brazilian real estate market. However, we note the existence of general awareness about the impacts caused by the generation and consumption of energy, both in environmental and economic terms, which could arouse the interest of conscious consumers. In addition, it is clear that the presentation of performance and consumption savings data is extremely useful for investors, owners and lessees of properties and is a driver for consumers to purchase and use more efficient properties. As such, there is significant space for growth in
sustainable residential real estate and respective financial viability will depend on exploration of the savings generating during operations compared with the increase in the sale price. As such, this paper intends to contribute to the decision-making process on investments in sustainability among developers in the city of Rio de Janeiro, as well as to bring the discussion about optimizing properties to prominence among consumers.

Keywords
Sustainability; real estate; financial viability; multifamily housing in Rio de Janeiro.