Returning Green Through Engineering: Utilization of Monte Carlo Simulation in Assessing Potential Lifetime Value of Conventional and Sustainable Building

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ABSTRACT--- Entering into the age of information where you can quickly access almost anything that happens globally has proven itself beneficial. This study was conducted to assess the performance of conventional buildings and sustainable or green buildings in terms of their potential lifetime value. By analyzing the standard specification of green buildings, people can have a better understanding of this innovation. Data gathered through statistics, literature review, and evaluation from companies, will determine the quantitative information for the creation of the Mathematical Model by the use of Monte Carlo simulation. The Monte Carlo simulation was executed using a software to provide histograms. In order to create scenarios to produce various results, a What-If analysis was also conducted. Consequently, evaluation and analysis of the costs of conventional and green building, gave way for the researcher to make a conclusion with regards to their efficiency. The validity of the results was determined based on anecdotal information by professionals who practiced building sustainable infrastructure. Nevertheless, this research serves as a pilot study to identify the breakeven points between conventional and green buildings. Furthermore, the researcher believes that a deeper enhancement of the data might yield to more accurate results.

Index Terms—Conventional Building, Green Building, Mathematical Model, Monte Carlo simulation

I. INTRODUCTION

Conventional building refers to the traditional method of construction that utilizes large amounts of energy for its construction and operations. Thus, leading to an increase in monthly utility bills per household or owner. It can refer to a house, a condominium, town houses, and other infrastructure. On the other hand, green building refers to sustainable or high performance building that uses less amount of energy by the application of processes that are environmentally responsible and resource-efficient for its construction and operation [1].

But the question of the affordability of green buildings may be a hindrance for some [2]. Many individual knew that this green building technology is expensive that only those people with a higher income can afford it. Hence, the researcher was moved to make this research to assess the most proficient and cost effective way in building green and conventional residential houses.

Through the use of Monte Carlo simulation, a factual probabilistic strategy to configure analyses or reproductions, and to think about the nondeterministic likelihood appropriation of the components and the reactions [3], the researcher came up with a mathematical model using the data gathered in the study. It analyzes the costs of utility bills and the repair and maintenance costs to determine the yearly costs of a conventional building vis-a-vis a green building. By doing so, the researcher seek to help individuals decide their preferred type of house in the future. It will also make a way for an individual to decide what would be his/her desired house.

This study is limited to the design, development and evaluation (validity and reliability) of the mathematical model that will be used to relate the behavior of lifetime cost of conventional versus green building. The estimation of the cost will be based only on construction cost, repair and maintenance cost, electricity and water consumption cost. The simulation study is limited to relating these aforementioned variables to conventional and green building lifetime cost as the researcher believes that these variables are measurable and are considered as the top factors that directly impact building maintenance costs.

This is a quantitative study that will mainly rely on simulation results. The Monte Carlo simulation will be implemented using the R Studio software. This study intends to accomplish a better decision making when it comes to the house that they would like to have by means of figures through the help of Monte Carlo simulation and on the other hand it doesn't have to do with which one is the best because both have their own advantages and disadvantages.

This simulation study reveals only the potential lifetime cost of green building versus conventional building. The researcher used the term 'potential' so as to highlight employing assumptions and guided estimates to come up with costing simulations.

The study also focuses on the lifetime cost of residential houses that are only 120 square meter that houses eight individuals in total [4]. The estimates and assumptions will solely be based on this scenario.

It is also known to the researcher that there is very limited data on green building costing and hence, scenarios are created to mimic the probable behavior of annual building cost. These estimates are deterministic, relative to the conventional building costing.

Revised Manuscript Received on December 22, 2018.

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The data for conventional building only spans for ten years, and to be able to get the breakeven points for green building scenarios that are more costly than others (i.e. twice the construction cost of conventional counterparts), the researcher predicted 20 more years worth of data and this might cause overestimation of values at the farther end of the series.

This study intends to help you decide whether building a sustainable house is more cost-efficient through analysis of results gathered using the Monte Carlo simulation. The researcher also wants to give you a rough idea of how beneficial and costly a green building is. A proper care for everything will really make an impact but then the question is, 'how can you make an impact?'

II. STATEMENT OF THE PROBLEM AND SIGNIFICANCE OF THE STUDY

The main objective of this research is to assess utilizing Monte Carlo the most proficient and cost effective way in building green and conventional residential houses. Specifically, the study will address the following,

1. Assess the standard specifications for a house to be considered green building.
2. Identify, compare and analyze the different costs and maintenances of each houses that will fabricate the most proficient and cost effective way.
3. Develop a mathematical model to determine the projected economical cost of each design through Monte Carlo Simulation.
4. Analyze and compare their cost into what year will the Green Building and Conventional Building be proficient and cost effective and in what year will they be break-even.
5. Evaluate the effectiveness of the mathematical model through presenting to professionals.

This study aims to help builders, contractors, professionals and home owners to understand the green building and its benefits. It aims to broaden the perspective of individuals towards leveraging on building green structures instead of relying to traditional methods of construction.

Essentially, this paper seeks to help people understand that in the long run, there will be savings on utilities in green building and hence, makes it cheaper to maintain in the future. This study is tailored for the appreciation of green building in the Philippines by providing insights as to how much resources will be saved in the future, as compared to relying to conventional building infrastructures. Furthermore, this study shows when the breakeven point will happen and what factors affect these changes in costing.

Most importantly, this serves as a guide to researchers and research practitioners who want to study green building further. This provides benchmark values and estimates that may serve as guide to lead researchers to pursue more sophisticated methods in identifying actual behaviors of green building, especially in the Philippine setting.

III. CONCEPTUAL FRAMEWORK AND METHODOLOGY

Fig. 1 shows the conceptual framework of this study that highlighted the major phases, steps, and procedures needed to be known to meet its main and specific objectives.

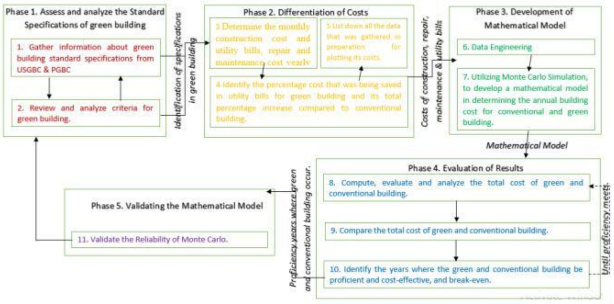

Fig. 1: Conceptual Framework

This research sought to identify the most cost-effective way to build a residential house, which could either be a conventional building or a green building. It tried to explore the variables that a person needs to consider in choosing between owning a traditional house or shifting to a more eco-friendly home. If only the construction cost will be considered in choosing the desired type of housing, i.e. looking only at short-term variables that affect the annual cost of a house, then it can be an easy choice: choose the house with cheaper materials, cheaper labor and essentially, cheaper construction cost. But that isn't the case.

This research discovered the effects of not only short-term variables, but also the impact of long term factors, such as repair and maintenance costs and utilities cost, among many others. Due to lack of data points, the researcher employed a simulation study to mimic the behavior of these variables, and compare these values against scenarios for green building that are created by the researcher that are based on literature and articles.

Phase 1: Assess and analyze the Standard Specifications of green building.

The first phase allowed us to gather, review and analyze information regarding green building to come up with standard specifications. This was a research-intensive phase. Most of the data gathering took place within the PGBC (Philippine Green Building Council) premises. Data gathering included using library archives and documents, interviewing green building professionals and consulting with online resources, especially for the purpose of identifying other international standards as implemented by LEED (Leadership in Energy and Environmental Design), under USGBC (United States Green Building Council).

Phase 2: Differentiation of Costs

Since the researcher already knows the specifications and have gained additional learning with regards to green building, the next thing that was considered was to identify the total increase of cost in green building compared to the conventional building in terms of monthly cost of utility bills; the yearly cost of repair and maintenance.

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The researcher gathered data of construction cost per square meter from PSA (Philippine Statistics Authority) that were available in their website. While the data for the cost of electricity per kWh (kilowatt-hour) were also available in the website of MERALCO (Manila Electric Railroad And Light Company). For MWSS (Metropolitan Waterworks and Sewerage System) data, the researcher went directly to their company to request a form regarding the cost of water per cubic meter which will take about 15-30 days before the researcher was able to get the data. While the data that was gathered for repair and maintenance was done in an article that was read by the researcher [5].

Phase 3: Development of Mathematical Model

The researcher determined the potential lifetime costs of conventional and green residential houses, data on the following items were collected:

Construction costs for residential houses (February 2002 – July 2018) [6].

Water utilization costs from Maynilad (January 2012 – December 2018) and Manila Water (January 2009 – December 2018) under MWSS [7].

Generation charges from Meralco (January 2009 – December 2018) [8].

The construction cost data contained a quarterly average of the estimated cost of construction per square meter (sqm). These quarterly averages were converted into monthly averages, for the purpose of creating monthly estimates. For the purpose of this simulation, few assumptions on the data were established:

The size of the residential house to be studied is 120 sqm, hence to get the actual construction cost: Potential Construction Cost (PCC)

$$PCC = ConstructionCost \,/\, sqm * 120 \longrightarrow \quad (1)$$

2. The construction cost per sqm for each quarter are assumed to be the average across the months included in the quarter, hence the monthly cost reflected in the data used in the simulation could have removed the random variations across the months.

Since the construction data available to the researcher were only until July 2018, a simple forecasting technique was utilized to obtain the construction costs until December 2018. The researcher leveraged on Holt-Winter's forecasting to generate the missing five (5) periods, from August 2018 to December 2018.

The water utilization cost data was obtained from two (2) sources, one from Maynilad and one from Manila Water. These data reflected the potential cost of utilization of water among residential buildings. Data from both sources contained billed volume per month, billed amount per month and the average price paid by each household. In order to create a unified water utilization costing data, the values from the two sources were aggregated by getting the averages.

It was assumed that the average consumption of water per capita is around 172.5 L [9]. For a household comprised of 8 residents, the researcher was able to generate the water utilization per month using the following formula: Monthly Water Consumption Cost (MWCC)

$$MWCC = AveWatCons \,/\, Cum * 172.5 * 8 * 30 * 1000 - \quad (2)$$

As for the electricity cost, cost per kilowatt hour (kWh) was obtained from Meralco for the years 2009-2018. The cost reflect only the generation cost, not including the taxes, miscellaneous fees and distribution charges as reflected on the electricity bill. Also, it was assumed that the average electricity consumption per household per day is around 10 kWh. Hence, to compute for the monthly electricity consumption, the researcher used the following formula: Monthly Electricity Consumption Cost (MECC)

$$MECC = AveEleCons \,/\, kWh * 10 * 30 \longrightarrow \quad (3)$$

Eq. (2) & (3) are both multiplied by 12 to reflect the potential yearly cost of consumption of the mentioned utilities. Yearly Water Consumption (YWCC) & Yearly Electricity Consumption Cost (YECC).

$$YWCC = MWCC * 12 \longrightarrow \quad (4)$$

$$YECC = MECC * 12 \longrightarrow \quad (5)$$

This was done except for the year 2009 wherein the multiplier is only 6, as it was assumed that the construction will continue for six months.

The computations for the total construction costs of both green and conventional building is as follows;

Computations for total cost of construction in conventional building.

For $i = 1$:

$$Vi = Ci + Wi + Ei$$

For $i > 1$:

$$Vi = V(i\text{-}1) + Ci + Wi + Ei + Ri$$

Where Ci is the construction cost at year i, Wi is the water expenses cost for year i, Ei is the electricity expenses cost for year i, Vi is the lifetime value cost of a building at year i, Ri is the repair cost for year i; Hence, $Ri = \alpha \bullet Ci$, where α is the proportionality factor of repair cost wrt construction cost.

Computations for total cost of construction in green building

For $i = 1$:

$$Gi = (1 + \beta j)\, Ci$$

For $i > 1$:

$$Gi = G(i\text{-}1) + (1 - \gamma j\,)Wi + (1 - \delta j)\, Ei + (1 - \varepsilon j)\, Ri$$

Where Gi is the lifetime value cost for green building at year i, βj is the proportionality factor for green building construction cost wrt conventional for j^{th} scenario, γj is the percentage decrease in cost of utilization of water for j^{th} scenario, δj is the percentage decrease in cost of utilization of electricity for j^{th} sceanario, εj is the proportionality factor of repair cost wrt construction cost for j^{th} scenario, $Ri = (1 + \beta i\,) \bullet Ci \bullet \varepsilon j$

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In order to extend the number of observable points in the data set, a Monte Carlo simulation was implemented. All the results that will be presented in this paper are generated through R Studio.

Conventional Building

The simulations were based on the actual observable distribution of the data. For the purpose of this study, a triangular distribution with parameters minimum (the lowest value in the array), maximum (the highest value in the array) and the mode (the most likely value in the array, usually the mean), were used as basis for the simulation. The values for the parameters were obtained for each variable to be simulated: Construction cost, annual water consumption cost and annual electricity cost, and these were done per year (from the assumed year of construction 2009 to 2018).

Except for year 2009, a repair or maintenance cost (RC) was computed. This was based on the current construction cost for that year (which is simulated), multiplied by a factor of 1% (for the first five years after construction) and 4% (for more than five years). A total of 10,000 simulated values for construction, annual water and electricity costs were generated based on their corresponding triangular distribution parameters.

For the year 2009, the annual building cost was computed as follows:

Annual Building Cost (2009) = YECC6+YWCC6+CC6
On the other hand, the annual building cost for the rest of the years was computed as follows:

Annual Building Cost (2010-2018) =

YECC12+YWCC12+RC12

Given the assumptions and parameters specified above, simulation results were generated for the construction, water and electricity cost, along with the annual building cost for year 2009. For the next years, simulations were created taking into account the repair cost (in place of the construction cost). Once the total costs were generated, the researcher obtains the 20^{th}, 50^{th} and 80^{th} percentile. These were then plotted across all the years against their green building cost counterpart.

Green Building

It was understood that there were very limited data on green building costing. To facilitate the simulation study, multiple scenarios were generated based on the existing and observable values of conventional buildings. In essence, a what-if analysis was conducted to generate ranges of possible values for green building yearly cost, which will be used to compute for the potential lifetime cost. A what-if analysis is a way to create potential scenarios that can capture behavior of variables that don't have actual values by specifying different combinations of parameters. These scenarios are as follows:

TABLE I: List of Scenarios Created for Green Building Construction Including the Parameters for the Construction Cost, Water Consumption Cost and Electricity Cost

Scenario #	Construction	Water	Electricity
Scenario 1	10	35	20
Scenario 2	10	35	80
Scenario 3	10	40	20
Scenario 4	10	40	80
Scenario 5	20	35	20
Scenario 6	20	35	80
Scenario 7	20	40	20
Scenario 8	20	40	80
Scenario 9	100	35	20
Scenario 10	100	35	80
Scenario 11	100	40	20
Scenario 12	100	40	80

For scenario 1, the green building cost is 10% higher than the construction cost of conventional homes, with a 35% and 20% lower water and electricity consumption. For scenario 2, the green building cost is 10% higher than the construction cost of conventional homes, with a 35% and 80% lower water and electricity consumption. For scenario 3, the green building cost is 10% higher than the construction cost of conventional homes, with a 40% and 20% lower water and electricity consumption. For scenario 4, the green building cost is 10% higher than the construction cost of conventional homes, with a 40% and 80% lower water and electricity consumption.

Scenario 5 shows that the green building cost is 20% higher than the construction cost of conventional homes, with a 35% and 20% lower water and electricity consumption while Scenario 6 shows that the green building cost is 20% higher than the construction cost of conventional homes, with a 35% and 80% lower water and electricity consumption. On the other hand, scenario 7 shows that the green building cost is 20% higher than the construction cost of conventional homes, with a 40% and 20% lower water and electricity consumption. Scenario 8 shows that the green building cost is 20% higher than the construction cost of conventional homes, with a 40% and 80% lower water and electricity consumption.

Scenario 9 shows that the green building cost is twice than the construction cost of conventional homes, with a 35% and 20% lower water and electricity consumption. Scenario 10 shows that the green building cost is twice than the construction cost of conventional homes, with a 35% and 80% lower water and electricity consumption. Scenario 11 still shows that the green building cost is twice than the construction cost of conventional homes, but with a 40% and 20% lower water and electricity consumption. Lastly, scenario 12 shows that the green building cost is twice than the construction cost of conventional homes, with a 40% and 80% lower water and electricity consumption. These modified values are then used for the simulations.

Similar to what the researcher did in the simulation of annual costs for conventional homes, repair costs are calculated for years 2010-2018, as seen on the following charts for year 2010 based on scenario 1 parameters.

Phase 4: Evaluation of Results

The researcher already have a mathematical model that was used for the evaluation of results. In this phase computation, evaluation and analyzes were done to produce the total cost of green and conventional building. The next part is to compare it with one another in order to identify in which year the green and conventional building became proficient and break-even which is also the output of this phase in preparation for the validation of the mathematical model that was used. Evaluation of results were done at the library. The data cost gathered were evaluated. In this phase, the researcher will use narrative analysis in order to evaluate the results that will be needed in the preceding steps.

Phase 5: Validating the Mathematical Model

In order for the researcher to validate the mathematical model, the data where the green and conventional building became proficient and break-even must be provided. This will make a way for the researcher to test the results of present costs using the mathematical model that was developed after testing in order to validate the reliability of the model.

If the result is far from the present cost, the researcher can add another simulation to the program until it creates a little discrepancy on it. The main objective of Monte Carlo simulation in this research is to create the wisest decision with regards to the desired house that an individual can have.

In order for the researcher to validate the reliability of Monte Carlo he should be able to present it to professionals who practices "Green Building" because data with regards to the cost of green building is insufficient to be able to validate it using completed projects. Professionals have the experience in the said field that is why they are the most suited people to validate the reliability of the study. Narrative analysis and observation is very suitable in testing and validating the mathematical model of Monte Carlo.

IV. RESULTS AND DISCUSSION

In this chapter the researcher was able to discuss the accomplishment of the phases and stages in the methodology, results, analysis, recommendations and interpretation of the study. It consists of the standard specifications of both buildings, the evaluation of their costs, break-even points in determining the Rate Of Investments in each building, when and where will they be efficient and proficient, mathematical modelling and the use of Monte Carlo simulation and its interpretation.

It was stated in the previous sections that the construction data available to the researcher is only until July 2018, a simple forecasting technique is utilized to obtain the construction costs until December 2018. The researcher leveraged on Holt-Winter's forecasting to generate the missing five (5) periods, from August 2018 to December 2018. The following chart shows the decomposed time series plot

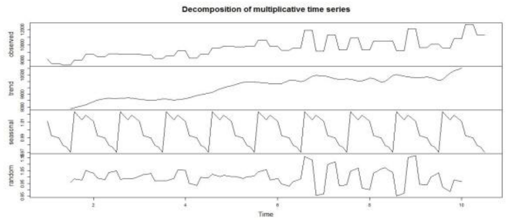

Fig. 2: Decomposed Time Series Plot of Construction Cost from 2009-2018 Using a Multiplicative Seasonality Model

Decomposing the time series reveals the trend, seasonality and random variations on the values of construction costs. Looking at the observed values, the fluctuations in the graph become wider at the ending series than the beginning series. Hence, a multiplicative model is utilized for forecasting. The graph below shows the result:

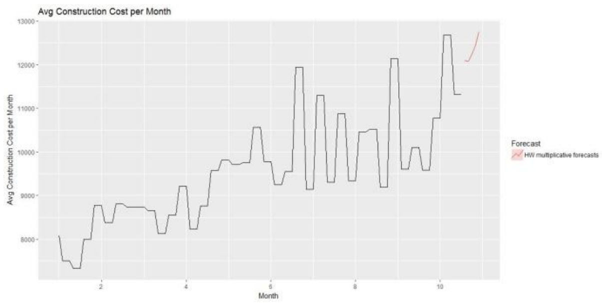

Fig. 3: Time Series Plot of Construction Cost from 2009-2018

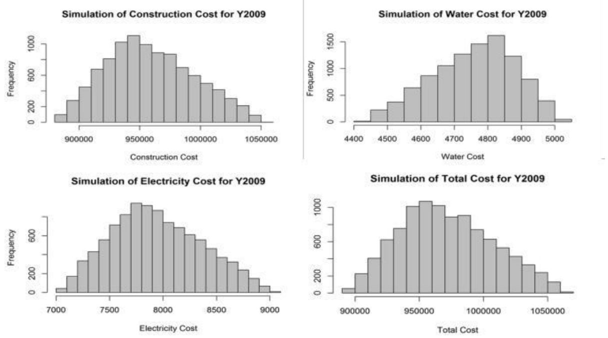

Fig. 4: Histogram Charts of the 10,000 Simulated Values for Construction Cost, Water Cost, Electricity Cost and Annual Building Cost for Year 2009

Given the completed construction costs generated through forecasting, along with the utilization costs, assumptions and parameters specified in the methodology, simulation results are shown above for year 2009 and below for year 2010. Similar to what the researcher did in year 2010 simulation of annual costs are calculated for year 2011-2018, rest of the chart is enclose in RStudio software that includes simulations of scenario 1-12 (2009-2018) for green building.

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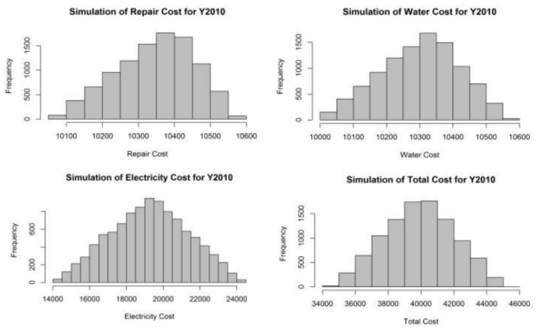

Fig. 5: Histogram Charts of the 10,000 Simulated Values for Repair Cost, Water Cost, Electricity Cost and Annual Building Cost for Year 2010

Getting the Break-even point

From the simulations obtained from conventional building lifetime cost versus green building lifetime cost, an overlay of the plots are generated in order to determine at which point the total cost of the building (inclusive of construction cost, water, electricity and repair costs) for green building models achieve the same total cost as conventional building models. Since there are no actual figures for green buildings, the 12 scenario values will be plotted against the conventional building metrics. For the purpose of illustration, the 50th percentile will be plotted.

TABLE II: 50th Percentile Values of Conventional Building's 10-Year Cost versus Green Building's 10-Year Cost Simulated Using Scenarios 1-4

Year	Conv	Scen_1	Scen_2	Scen_3	Scen_4
2009	968,187	1,060,149	1,055,945	1,058,641	1,054,875
2010	1,008,121	1,089,899	1,074,149	1,087,885	1,072,561
2011	1,048,141	1,119,686	1,092,609	1,117,143	1,090,483
2012	1,092,806	1,152,884	1,113,032	1,149,707	1,110,290
2013	1,136,820	1,185,434	1,134,144	1,181,617	1,130,754
2014	1,218,612	1,246,074	1,182,906	1,241,544	1,178,930
2015	1,297,288	1,304,154	1,230,829	1,298,970	1,226,265
2016	1,374,649	1,361,089	1,279,272	1,355,383	1,274,059
2017	1,453,751	1,419,485	1,328,111	1,413,175	1,322,226
2018	1,541,524	1,484,311	1,382,427	1,477,366	1,375,928

Based on Fig. 6, if scenario 1 and 3 will hold, that is, the cost of constructing a green building is 10% higher than its conventional counterpart, that lower the cost of consumption of water by 35-40% and with 20% lower electricity consumption, the breakeven point is around seven (7) years.

On the other hand, if scenario 2 and 4 will hold, that is, the cost of constructing a green building is 10% higher than its conventional counterpart, that lower the cost of consumption of water by 35-40% and with an 80% lower electricity consumption, the breakeven point is around five (5) years.

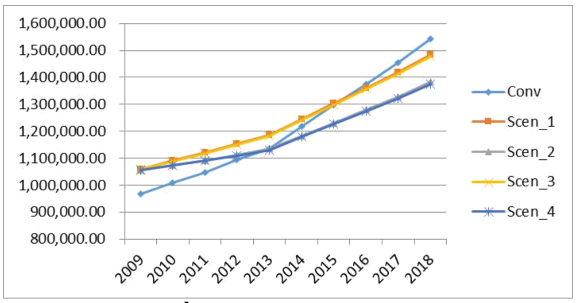

Fig. 6: Plot of 50th Percentile Values of Conventional Building's 10-Year Cost versus Green Building's 10-Year Cost Simulated Using Scenarios 1-4ib

TABLE III: 50th Percentile Values of Conventional Building's 10-Year Cost versus Green Building's 10-Year Cost Simulated Using Scenarios 5-8

Year	Conv	Scen_5	Scen_6	Scen_7	Scen_8
2009	968,187	1,155,860	1,151,177	1,155,476	1,150,843
2010	1,008,121	1,185,599	1,169,384	1,184,703	1,168,532
2011	1,048,142	1,215,397	1,187,849	1,213,971	1,186,454
2012	1,092,807	1,248,592	1,208,284	1,246,519	1,206,255
2013	1,136,820	1,281,158	1,229,391	1,278,423	1,226,721
2014	1,218,612	1,341,756	1,278,181	1,338,336	1,274,891
2015	1,297,289	1,399,814	1,326,146	1,395,784	1,322,216
2016	1,374,649	1,456,722	1,374,597	1,452,087	1,370,002
2017	1,453,751	1,515,178	1,423,406	1,509,853	1,418,215
2018	1,541,524	1,580,018	1,477,734	1,574,032	1,471,885

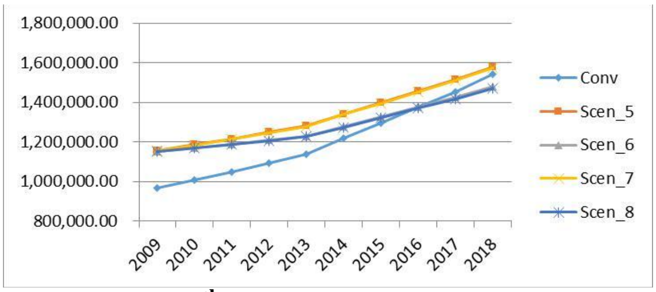

Fig. 7: Plot of 50th Percentile Values of Conventional Building's 10-Year Cost versus Green Building's 10-Year Cost Simulated Using Scenarios 5-8

Based on Fig. 7, if scenario 6 and 8 will hold, that is, the cost of constructing a green building is 20% higher than its conventional counterpart, that lower the cost of consumption of water by 35-40% and with an 80% lower electricity consumption, the breakeven point is around eight (8) years.

On the other hand, if scenario 5 and 7 will hold, that is, the cost of constructing a green building is 20% higher than its conventional counterpart, that lower the cost of consumption of water by 35-40% and with a 20% lower electricity consumption, the breakeven point is more than ten (10) years. To estimate this breakeven in the future, forecasts are created for a few years more using the Holt-Winters technique. Construction cost, water and electricity costs are forecasted for the next three more years that is until 2021.

Based on Fig. 8, if the extend the simulations of lifetime costs of conventional and green buildings, it can be observed that the breakeven point happens after the 11th year.

TABLE IV: 50th Percentile Values of Conventional Building's 13-Year Cost versus Green Building's 13-Year Cost Simulated Using Scenarios 5 and 7

Year	Conv	Scen_5	Scen_7
2009	968,187.03	1,155,859.67	1,155,476.48
2010	1,008,121.16	1,185,599.19	1,184,703.34
2011	1,048,141.71	1,215,396.77	1,213,970.93
2012	1,092,806.63	1,248,592.33	1,246,519.04
2013	1,136,820.08	1,281,157.55	1,278,423.43
2014	1,218,612.48	1,341,756.14	1,338,336.26
2015	1,297,288.96	1,399,813.82	1,395,784.16
2016	1,374,649.44	1,456,721.52	1,452,086.95
2017	1,453,751.31	1,515,178.22	1,509,853.10
2018	1,541,524.17	1,580,017.82	1,574,031.70
2019	1,636,055.43	1,649,905.63	1,643,234.38
2020	1,734,551.48	1,722,726.89	1,715,302.87
2021	1,836,956.93	1,798,432.64	1,790,263.44

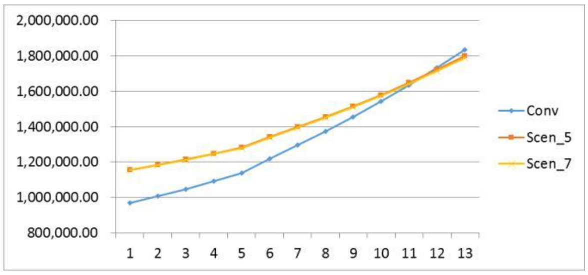

Fig. 8: Plot of 50th Percentile Values of Conventional Building's 13-Year Cost versus Green Building's 13-Year Cost Simulated Using Scenarios 5 and 7

TABLE V: 50th Percentile Values of Conventional Building's 10-Year Cost versus Green Building's 10-Year Cost Simulated Using Scenarios 9-12

Year	Conv	Scen_9	Scen_10	Scen_11	Scen_12
2009	968,187	1,918,008	1,914,830	1,920,836	1,914,851
2010	1,008,121	1,947,779	1,933,040	1,950,077	1,932,536
2011	1,048,142	1,977,575	1,951,501	1,979,317	1,950,464
2012	1,092,807	2,010,753	1,971,932	2,011,883	1,970,268
2013	1,136,820	2,043,308	1,993,046	2,043,786	1,990,733
2014	1,218,612	2,103,917	2,041,844	2,103,810	2,038,893
2015	1,297,289	2,161,940	2,089,804	2,161,237	2,086,167
2016	1,374,649	2,218,941	2,138,293	2,217,532	2,133,960
2017	1,453,751	2,277,324	2,187,092	2,275,324	2,182,096
2018	1,541,524	2,342,156	2,241,425	2,339,476	2,235,747

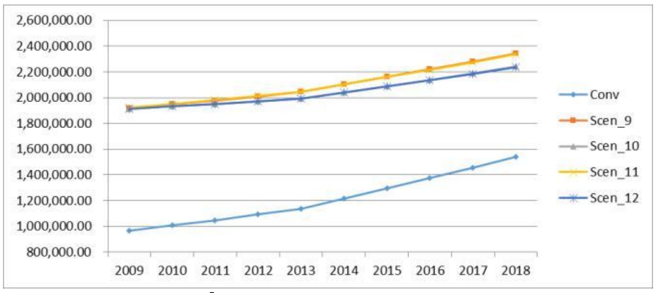

Fig. 9: Plot of 50th Percentile Values of Conventional Building's 10-Year Cost versus Green Building's 10-Year Cost Simulated Using Scenarios 9-12

Based on Fig. 9, if scenarios 9 to 12 will hold, that is, the cost of constructing a green building is twice than its conventional counterpart that lower the cost of consumption of water by 35-40% and with a 20-80%

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lower electricity consumption, the breakeven point is more than ten (10) years. To estimate this breakeven in the future, forecasts are created for a few years more using the Holt-Winters technique. Construction cost, water and electricity costs are forecasted for the next 20 more years, which is until 2038.

TABLE VI: 50th Percentile Values of Conventional Building's 30-Year Cost versus Green Building's 30-Year Cost Simulated Using Scenarios 9-12

Year	Conv	Scen_9	Scen_10	Scen_11	Scen_12
2009	968,187	1,918,008	1,914,830	1,920,836	1,914,851
2010	1,008,121	1,947,779	1,933,040	1,950,077	1,932,536
2011	1,048,142	1,977,575	1,951,501	1,979,317	1,950,464
2012	1,092,807	2,010,753	1,971,932	2,011,883	1,970,268
2013	1,136,820	2,043,308	1,993,046	2,043,786	1,990,733
2014	1,218,612	2,103,917	2,041,844	2,103,810	2,038,893
2015	1,297,289	2,161,940	2,089,804	2,161,237	2,086,167
2016	1,374,649	2,218,941	2,138,293	2,217,532	2,133,960
2017	1,453,751	2,277,324	2,187,092	2,275,324	2,182,096
2018	1,541,524	2,342,156	2,241,425	2,339,476	2,235,747
2019	1,636,055	2,412,070	2,299,511	2,408,710	2,293,193
2020	1,734,551	2,484,874	2,360,392	2,480,812	2,353,368
2021	1,836,957	2,560,553	2,424,029	2,555,789	2,416,249
2022	1,943,336	2,639,163	2,490,416	2,633,651	2,481,898
2023	2,053,688	2,720,674	2,559,537	2,714,376	2,550,312
2024	2,167,984	2,805,058	2,631,424	2,797,987	2,621,428
2025	2,286,245	2,892,363	2,706,112	2,884,473	2,695,290
2026	2,408,475	2,982,561	2,783,536	2,973,857	2,771,887
2027	2,534,586	3,075,699	2,863,720	3,066,121	2,851,208
2028	2,664,677	3,171,727	2,946,711	3,161,265	2,933,268
2029	2,798,704	3,270,654	3,032,429	3,259,292	3,018,090
2030	2,936,744	3,372,479	3,120,885	3,360,209	3,105,617
2031	3,078,742	3,477,249	3,212,107	3,464,022	3,195,986
2032	3,224,682	3,584,810	3,306,064	3,570,683	3,289,003

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2033	3,374,581	3,695,319	3,402,759	3,680,235	3,384,749
2034	3,528,364	3,808,801	3,502,274	3,792,699	3,483,222
2035	3,686,149	3,925,128	3,604,519	3,908,024	3,584,453
2036	3,847,874	4,044,325	3,709,564	4,026,215	3,688,425
2037	4,013,559	4,166,448	3,817,367	4,147,284	3,795,153
2038	4,183,266	4,291,495	3,927,895	4,271,226	3,904,625

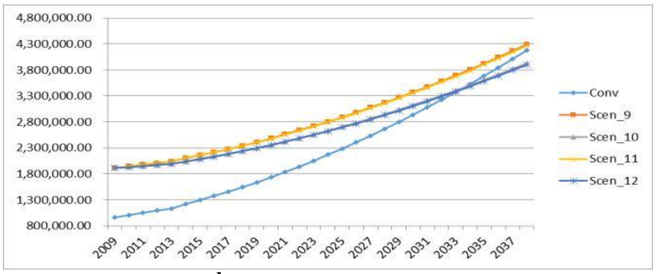

Fig. 10: Plot of 50th Percentile Values of Conventional Building's 30-Year Cost versus Green Building's 30-Year Cost Simulated Using Scenarios 9-12

Based on the Fig. 10, if scenario 10 and 12 will hold, the breakeven point is around 25 years. On the other hand, if scenario 11 and 12 will hold, the breakeven point might be more than 30 years.

V. CONCLUSION

The simulations done using Monte Carlo produced results labor force. However, looking at the long term benefits of a green building in terms of water and electricity saving, the lifetime cost of a green building will in turn equate to the lifetime cost of conventional buildings.

Based on the results, if green building construction will up to 20% conventional buildings and is estimated to save up to 80% of electricity usage cost and 40% water consumption cost, it is expected that its lifetime value will breakeven with its conventional counterpart in less than 10 years. On top of that, after 10 years, the cost of maintaining a green building will actually be less costly than a conventional building.

In some cases, it could be more than 10 years, even more than 30 years but this will be depending on the actual cost of green building in terms of construction as compared to its conventional building counterparts. Based on the study, even if the cost of constructing a green building is twice than the usual cost for regular buildings, it could still reach abreakeven point because of the savings on utilities and other maintenance costs.

Essentially, green buildings are less prominent than conventional buildings because of costly construction. But looking at the long term benefits of green buildings provides insight as to how much will the residents save in terms of maintaining the household.

ACKNOWLEDGEMENT

The authors would like to thank the Department of Science and Technology Development for Technology (DOST-ERDT) for the funding of this study

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