ARE GREEN BUILDINGS ECONOMICALLY SUSTAINABLE? A LCC APPROACH

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ABSTRACT

In the context of Sri Lanka, the number of green certified buildings is still at a minimal level and the reason could be attributed to green building investors who continue to perceive that green buildings are costly and the initial cost premium ranges from 20 to 25% and fail to appreciate the subsequent benefits in terms of running costs. However, in the global context, researchers have indicated that green building construction cost varies largely between -15 to 21% while only a little information is available on the status of operation and maintenance costs reduction. As part of the larger study which investigates the impact of sustainable features on life cycle cost of green buildings, this paper presents a comparison on life cycle cost of green certified industrial manufacturing building with that of a conventional building to establish the economic sustainability of green buildings. Quantitative data on the construction and running costs of green and conventional buildings were collected and analysed using Net Present Value. The analysis shows that the construction cost of green industrial manufacturing building is 28% higher than that of a conventional building while the reduction in running costs is 39%. Overall the green buildings offer an economic benefit of 50% savings over its life time. It is expected that the outcome of this research would contribute to the organisational learning of green built environment and thereby uplift the sustainable construction.

***Keywords**:Green Buildings; Green Rating Systems; Life Cycle Cost; Sri Lanka; Sustainable Features.*

1. INTRODUCTION

Green building creates environmentally responsible and resource-efficient structures and processes throughout its entire life-cycle beyond any classical building design concerns of economy, utility, durability and comfort (Environmental Protection Agency, 2017). Further, green buildings are said to be high performance building, focused to enhance the environment, social and economic sustainability pillars (Smith, *et al*, 2006). Green buildings reduce the environmental impacts significantly while using energy, water, and other resources efficiently by adopting various sustainable attributes such as sustainable sites, management, energy efficiency, water efficiency, materials and resources, indoor environmental quality, health and wellbeing etc.to resource conservation (USGBC, 2009). Given social, environmental and economic benefits, there exist some economic barriers which decide whether to execute a green building project or not. Amongst, perception of higher risk and investment costs (Hydes and Creech, 2000; Nelms, *et al*, 2005), lack of awareness among wider audience about major cost savings during operation (Ala-Juusela, *et al*, 2014), underestimating the potential cost savings, overestimating the capital costs of energy efficient measures and inadequate market value (Bartlett and Howard, 2000) are some of the significant barriers.

Morris and Langdon (2007) indicated that most of the buildings require a little or no additional cost to incorporate a reasonable level of sustainable design. However, Kats (2003), Stegall (2004), Nilson (2005) and Fowler and Rauch (2008) are of the view that the construction cost of a green building is higher than conventional building while there is a less operation cost. The authors further stated that usually higher premiums result in higher level of sustainability. Packard Foundation (2002) estimated that a premium of 0.9%, 1.3%, 1.5% and 2.1% of total hard costs which include excavation, foundation works, concrete flatwork, etc., is required to achieve LEED Certified, Silver, Gold, and Platinum for an office building, respectively. Another study conducted by Kats (2003) indicated that on average green cost premium is 0.66%, 2.11%, 1.82%, and 6.50% for Certified, Silver, Gold and Platinum respectively. A recently review of empirical evidence on green buildings cost premium shows that the green building cost premium is higher than that of conventional buildings and fall within a range from 0% to 21% Dwaikat and Ali (2016). A smaller percentage of the participants indicated that green buildings cost is less than their conventional counterparts and ranges from -4% to 0%. However, authors further concluded that there exists a significant gap in the quantified cost premiums and it is still questioned whether the green buildings cost more than its conventional counterparts. Yet, there is no conclusive answer to the question whether green buildings are economically sustainable?

According to researchers, the design cost of green buildings depend on several factors, including project location, building type, site conditions, local climate, and the familiarity with green design, modelling costs and time necessary to integrate sustainable building practices into projects and architectural and engineering design time (Kats, *et al*, 2008; Morris, 2007).Hence, the cost of green is highly subjective and previous studies demonstrated that cost-effective green designs are possible if sustainability goals, strategies and budgets are established and integrated in the pre-design stage (Morris, 2007; Kats *et al*., 2008). A visible limitation of the past studies is that the researchers were unable to quantify the running cost saving of the green buildings over its high construction cost. To that end, the current study compares the life cycle cost (LCC) of green and conventional buildings. LCC is a valuable tool to achieve cost efficiency in green building construction projects (Cole, 2000). The construction cost, the cost in use and the recovery cost should be considered at the outset of a construction project to identify the most economically viable project. In this end, there is a need to compare the LCC of green buildings with conventional buildings to address the issue of economic sustainability of green buildings.

In the Sri Lankan context, it was identified that the construction cost of green buildings is 20-25% higher than conventional buildings while the advantage gained is 10 times as much over the entire life of the building (Bombugala and Atputharajah, 2010). Further, Waidyasekara and Fernando (2012) stated that still fewer buildings have implemented the green concept in Sri Lanka due to lack of understanding among professionals about the period of achievement of economic savings of green buildings. Therefore, the extra investment cost needed for green buildings is found to be the primary barrier which restricts the implementation of green buildings in Sri Lanka. Green building investments are unattractive to those who expect fast investment returns. The foregoing review indicates that the cost commitment of green buildings is the prime concern and of contradictory views with respect to different contexts; type of building, climate condition, site conditions, etc. The contradictory nature of the previous studies in terms of construction cost premium of green buildings drove to current study. Further, the previous studies have no indication on running costs of green buildings compared to conventional buildings. The availability of quantitative evidence of running cost reduction in green buildings would enhance the investment on green buildings. The current study therefore compares the running cost of industrial manufacturing building and thereby establishes whether green buildings are economically sustainable?

2. FACTORS AFFECTING THE LCC OF GREEN BUILDINGS

Several studies have focused on comparison of green buildings with conventional buildings of similar type, size (Net Lettable Area), age, building tenancy and constructed in similar location (Packard Foundation, 2002; Kats, *et al*., 2003; Matthiessen and Morris, 2004; Langdon, 2007; Fullbrook and Woods, 2009).

Of them, Matthiessen and Morris (2004) highlighted that the cost of the green is influenced by demographic location: rural or urban, bidding climate and culture, local and regional design stages including codes and initiatives, intent and values of the project, climate, and timing of implementation, size of building and point synergies. Similarly, in an urban site the cost associated with storm water management, attempting to build green in an area where sustainable design is not a familiar concept, and contractors' unwillingness to bid are some other factors which could significantly impact the cost of the green project. It is likely to impact the cost of building, if the building owner and the design team are unwilling to invest time and cooperation that may be needed to reach the desired certification level.

Further, Kim, *et al*. (2011); Mapp, *et al*. (2011); Shrestha and Pushpala (2012) explained that building size, type, function, location, climate and type of certification as the factors affecting to green buildings. These varying factors which affect the LCC of green buildings are classified as major and sub-factors and given in Table 1.

Table 1: Factors Affecting the LCC of Green Buildings

Main Factor	Sub Factor	Source
Managerial	Materials selection does not comply with client's activities Usage of cheaper/sub-standard materials Usage of new materials with little behaviour's information Lack of skilled labour, faulty workmanship and uneducated labours Poor management by maintenance personnel Lack of building maintenance manuals Poor communication between maintenance parties Failure to execute maintenance at the right time Interdepartmental boundaries Accelerated maintenance work due to poor budgetary control Unqualified maintenance contractors Unavailability of maintenance contractors	El-Haram and Horner (2002); Matthiessen and Morris (2004); Omari (2015)
Social	User does not understand importance of operation and maintenance work End users' behaviours Cultural practices High expectation of tenants Improper use of the property Vandalism by the tenant Delay in reporting failures	El-Haram and Horner (2002); Al-Khatam (2003); Omari (2015)
Environmental	Demographic location Physical site conditions Climate Environmental considerations	Kim, *et al*. (2011) and Mapp, *et al*. (2011); Shrestha and Pushpala (2012)
Financial	Inadequate finance Poor financial control on site and when executing maintenance work Market conditions Poor financial support for maintenance work	Lai, Yik and Jones (2010); Omari (2015)
Technical	Design complexity Faulty design Faulty maintenance Low concern to future maintenance Failure to identify the true cause of defects Selection of sub-optimal maintenance strategy Unfamiliarity with maintenance methods Type of structure Availability of services Resource availability Aging of building	El-Haram and Horner (2002); Al-Khatam (2003); Saghatforoush, Trigunarsyah, and Too (2012); Omari (2015)
Morphology	Plan shape Size of building Wall to floor ratio Degree of circulation space Storey height Total height of the building Grouping of buildings	Belniak and Zima (2013); Cunningham (2013); Ashworth and Perera (2015)
Other	Bidding climate and culture Local and regional design standards, including codes and initiatives Intent and values of the project Timing of implementation Point synergies Legislative constraints Method of construction Political factors Method of procurement	El-Haram and Horner (2002); Al-Khatam (2003); Matthiessen and Morris (2004); Omari (2015)

3. RESEARCH METHODOLOGY

The study involved two major phases: (1) a comprehensive literature review was carried out into previously published journal articles, books, trade publications and thesis to identify the green cost premium in the global context, (2) a comparative analysis was performed between the life cycle cost of a green building and conventional building. A green building and a conventional building with similar physical and performance characteristics were selected with due considerations to year of construction, Net Internal Area (NIA), and occupancy rate. The green case was identified conveniently, then carefully selected the conventional case with similar characteristics. Relevant real-life cost data: construction, annualised and periodic operation and maintenance, simulated end life cost and green building cost savings data were collected through document analysis according to the standard cost categories of Building Maintenance Cost Information Service (BMCIS). The green building construction budget, and operation and maintenance expenditure budget records were used to collect the cost data. Simultaneously, physical and performance data such as constructed year, number of floors, NIA, life cycle, building height and number of occupants were collected from the selected green and conventional buildings. The Net Present Value (NPV) analysis was used to measure the LCC of green buildings. All the costs were escalated at assumed inflation rate and then discounted for the base year. The analysis was carried out for 50 years at the discount rate of 4.26% obtained from the Central Bank of Sri Lanka. Finally, a sensitivity analysis is performed to determine the effects due to changes in discount rates and life cycle of the selected building.

4. ANALYSIS AND FINDINGS

4.1. COST OF GREEN BUILDINGS VS. CONVENTIONAL BUILDINGS

Previous studies which have compared the green buildings with similar natured conventional buildings have contributed to raise the awareness among investors and developers on the cost benefits and feasibility of implementing green buildings. The comprehensive review of empirical findings indicates that the cost premium of green building differs in terms of building type, certification level, cost estimation methods and sample size, etc. An in-depth analysis of LEED-NC certified buildings revealed that high performance sustainable building projects required higher capital investment and the required capital was proportional to the intended LEED-NC rating (Kats, 2003). According to Kats (2003), the cost premium of the green project is likely to be on increasing cost trend with respect to higher levels of green certification. On the other hand, Nilson (2005) estimated the LEED Gold certification to be 0.82% of total construction costs for an office building in New York. Also, Stegall (2004) estimated that a premium of 1-3% of the total project cost is required for a new house that aims to achieve LEED Silver certification.

In another situation, Kats (2006) conducted a study on 30 green school projects that were built in 10 different states during 2001 and 2006. According to results of the study, it was found that green school design involved 1-2% additional cost when compared with a conventional design. Author further explained that green buildings offer benefits that were 20 times as large over a 20-year period. Savings in health and productivity costs due to increased earnings, reduction in respiratory diseases, and higher employee retention made up 85% of total whole life cost savings, with savings in energy, water and waste contribute to remaining 15%. Another study that analysed 150 recently completed conventional and green buildings in 33 states across United States and 10 other countries concluded that green buildings cost up to 4% more than conventional buildings while most of the buildings cost only 1-2% more than conventional buildings. The study also found that energy used in green buildings reduced by 33% on average, and that energy cost savings alone over a 20-year study period outweighed the construction cost premium paid in these buildings (Kats *et al.*, 2008). In this sense, this section analyses the empirical findings of previous studies in terms of type of building, methodology adopted, sample size used, and certification level and the outcome. Table 2 presents the summary of findings of twenty-five (25) previous studies.

Table 2: Summary of Previous Studies on Green Cost Premium

Type of Building	Methodology Adopted	Outcome	Source
Office	Cost analysis of re-designing 03 existing buildings to green	-0.3 to 1.3%	Xenergy and Sera Architects (2000)
Office	Single case study: comparative cost analysis of modelled cost of green building against market baseline	LEED Certified: 0.9%; Silver: 13.1% Gold:15.5% Platinum 21%	Packard foundation (2002)
Office, School	Cost comparative analysis - actual cost of 33 green buildings against conventional design estimated through participants' perception	Average:1.84% LEED Certified: 0.66% Silver: 2.11% Gold: 1.82% Platinum: 6.5%	Kats, *et al.* (2003)
Office	Meta-analysis of secondary research and unspecified analysis of actual cost of green	Soft costs: -1.5 to 3.1% Hard costs: 3 to 8%	Northbridge Environmental Management Consultants (2003)
Office and Courthouse	Cost comparative analysis - modelled costs of 02 green buildings against conventional	-0.4% to 8.1%	Steven Winter Associates (2004)
Office	Single case study: cost comparative analysis	0.82%	Nilson (2005)
Office	Unpaired t-test of actual green fit-out costs of 12 green buildings against 13 non-green fit-out costs	No statistically significant cost difference	Davis Langdon (2007)
Office	Cost comparative analysis - modelled costs of 20 green building against conventional	4 Star 3 to 7% 5 Star 7 to15%	Fullbrook (2007)
Office	Single case study – Cost comparative analysis	4 Star: 1.25% 5 Star: 4.37% 6 Star: 6.23% Unrated: 2.91%	Fullbrook and Woods (2009)
Office	Cost comparative analysis - actual cost of 17 green buildings against modelled cost of conventional	No statistically significant cost difference	Rehm and Ade (2013)
Academic, laboratory and library	Unpaired t-test - actual cost of 45 LEED seeking buildings against 93 non-LEED seeking buildings	No statistically significant cost difference, Majority: No additional cost	Matthiessen and Morris (2004)
School	Cost comparative analysis - 30 green buildings against conventional	Average: 1.7%	Kats (2006)
Academic	Unpaired t-test - actual costs of 22 green building against non-green buildings	No statistically significant cost difference	Matthiessen and Morris (2007)
House	Single case study: itemized cost impact analysis	LEED Silver: 17%	NAHB Research Centre (2009)

School	Cost comparative analysis - 30 green buildings against 30 conventional	46%, Mean construction cost per square foot is significantly higher	Shrestha and Pushpala (2012)
Residential	Cost comparative analysis – 15 green projects against 22 conventional	Cost per square foot - no statistically significant cost difference	USGBC (2009)
Commercial	Cost comparative analysis - 12 green commercial interior projects and 13 conventional	Cost per square foot: no statistically significant cost difference	USGBC (2009)
Residential	Single case study: cost comparative analysis	10.77%	Kim, *et al.* (2014)
Healthcare	Cost comparative analysis - cost of 13 green and buildings against conventional	0 to 5%	Houghton, *et al.* (2009)
Bank	Cost comparative analysis - 02 green and conventional	No statistically significant cost difference	Mapp, *et al*. (2011)
Office Academic Healthcare School Library	Single case study – cost comparative analysis	1.5 to 6.5% -15% 1.50% 5.70% 4.90%	Fullbrook, *et al*. (2005)
Office	Participants' Perception	LEED Certified: 1.2% Silver: 2.25% Gold: 3.37% Platinum: 7.66)	Kats, *et al*. (2010)
Schools	Participants' Perception	LEED Certified: 0.35% Silver: 1% Gold: 1.3% Platinum: 9.6%	Kats, *et al*. (2010)
Academic building	Participants' Perception	LEED Certified: 1.65% Silver: 1.8% Gold: 1.93% Platinum: 2.53%	Kats, *et al*. (2010)
General	Participants' Perception	-5 to 10% Majority: 5 to 10%	Ahn and Pearce (2007)
General Healthcare Higher education School Hotel Restaurant Residential	Participants' Perception Participants' Perception Participants' Perception Participants' Perception Participants' Perception Participants' Perception Participants' Perception	1 to 15% Majority: 6 to 10% 3 to 5% 3 to 5% 11 to 15% 3 to 5% 3 to 5% 6 to 10%	Building Design and Construction (2007)
General	Participants' Perception	1 to 10% Majority: 5 to 10%	Park, Nagarajan and Lockwood (2008)
General	Participants' Perception	0 to 18% Majority: 0 to 4%	Kats (2010)

As seen from Table 2, studies have focused on various types of buildings such as residential - high-rise apartments, office, education, and hotel buildings, etc. Whilst rarely considered the industrial manufacturing category. Various cost estimation methods have been used to find out the cost premium of green buildings. Amongst, estimation of green cost through the survey respondents is the least applied method and Rehm and Ade (2013) pointed out that this method is less reliable and the findings are biased from the selected respondents. Comparing actual cost of green buildings with actual or modelled cost of conventional buildings and comparing modelled cost of green buildings with the modelled cost of conventional buildings are other methods which employed in the empirical investigations to estimate the cost premium of green buildings. Most of the empirical studies were conducted by trade organizations where the methods used to model the cost of the buildings are unclear.

Further, the cost premium for these buildings based different green certification levels in BREEM, Green Star and LEED rating systems. The cost premium increases with the certification level, the buildings with higher level of green often require increased green cost premium than lower certification level. Amongst the selected buildings for the previous studies, majority of the studies were conducted on office buildings and reported the highest green premium (21%).

Table 3 presents a further scrutiny of the findings shown in Table 2, according to the cost premium of different types of buildings.

Table 3: Summary of Cost Premium for Green Building

Type of Building	**Number of Studies (Cost Premium %)**						**Total (%)**
	Less than 0%	0%	0 - 5%	0 - 10%	0 - 20%	Higher than 20%	
Office	2	2	1	5	1	1	48%
Schools/ Higher Education	1	2	3	3	1	1	44%
Residential/House		1		1	2		16%
Healthcare			3				12%
Library		1	1				8%
Laboratories		1					4%
Hotel/Restaurant			1				4%
Bank		1					4%
Courthouse	1						4%
Other	1	1		1	2		20%
Total	20%	36%	36%	40%	24%	8%	

According to Table 3, most of the previous studies have focused on office and school buildings and the cost premium of those buildings ranges between less than 0% to above 20%. In case of residential buildings, the cost of green premium falls within 0-20%. Other categories of buildings such as healthcare, library, laboratories, and hotels/restaurants require only 5% increased cost of construction. However, Mapp, *et al*. (2011) indicated that the bank buildings require no additional cost for incorporating green features.

These variations in green cost premiums among different types of buildings and inadequacy in methods adopted to assess the green cost premium have driven the current study to compare the life cycle cost of a conventional industrial building with a similar type of green building and confirm whether green buildings are economically sustainable. The green space for industrial manufacturing buildings has received the top most position with 18 out of 38 LEED certified green buildings in Sri Lanka to date.

The next section presents the life cycle cost analysis of two buildings: Green vs. Conventional.

4.2. PROFILE OF CASES

Having considered the factors influencing the sustainability, a conventional building constructed in similar location and climatic condition, with similar tenure, i.e. management style and quality, equal age and size of the selected green building was chosen. In addition, physical and performance characteristics such as year of construction, number of floors, shape, NIA, designed life cycle, building height and number of occupants were matched between the two buildings. Table 4 presents the profile of the selected two buildings.

Table 4: Profile of the Buildings

Building	**Year**	**Number of floors**	**Shape**	**NIA (m2)**	**Life Cycle**	**Building height(m)**	**Number of Occupants**	**Function**
Green	2013	1	Rectangular	3567	50	4.0	1310	Garment
Conventional	2013	2	Rectangular	4032	50	7.8	1340	Garment

As observed from Table 4, the year of construction, shape of the building and designed life cycle are similar for both buildings while the green building is smaller in terms of number of floors, building height, and NIA. However, these minor differences are not expected to affect the life cycle cost substantially.

4.3. LCC COMPARISON BETWEEN GREEN AND CONVENTIONAL BUILDINGS

As discussed in the methodology, the NPV of the two buildings were calculated for the analysis period of 50 years using a discount rate of 4.26%. Relevant cost data required for the NPV calculations were collected according to the standard cost categories suggested by Building Maintenance Cost Information Service (BMCIS). Table 5 illustrates the summary of comparison. All the costs were discounted back to year 2013 and normalised considering cost per m^2 of NIA.

Table 5: LCC between Green and Conventional Buildings

LCC	Green Building (GB) cost per m^2 (LKR)	Conventional Building (CB) cost per m^2 (LKR)	Green Building Cost Impact $\frac{\text{PV of GB} - \text{PV of CB}}{\text{PV of GB}} * 100\%$
Construction Cost	81,081.68	58,699.34	28%
Running Cost	401,218.27	557,873.96	-39%
NPV	482,299.95	616,573.31	-28%
	Validation		
Total Cost Saving of Green Building (Energy cost-40%, Water cost-50%, Waste Recycling-95%, Reduced absenteeism-2%)			50%
Ddt: Cost of implementing and maintaining sustainable features of Green Buildings (Approx.)			22%
Net Effects due to sustainable features			28%

According to Table 5, the construction cost of the green building is 28% higher than that of the conventional building. However, running cost is comparably less than that of conventional building by 39% due to the 50% of benefits accrued through life cycle of green building. According to the data collected from the selected green building, the green building saves 40% of energy cost, 50% of water cost, 95% of waste recycling and 2% of cost due to reduced absenteeism. From this 50% of saving 22% cost is trade off due to the cost of implementation and maintaining of sustainable features incorporated to the green building. Therefore, this deduction ultimately gives 28% of net saving. This similar saving is obtained through LCC comparison between green and conventional buildings. Therefore, it is safe to conclude that the LCC of green building is 28% less than that of a conventional building.

4.4. SENSITIVITY ANALYSIS OF LCC

It is often required to carry out a sensitivity analysis in life cycle cost analysis in order to ensure the consistency of the findings with respect to changes in assumptions made. The two key assumptions used for this study are discount rate of 4.26% and the life cycle of 50 years. Therefore, a sensitivity analysis was performed to examine how variations across range of uncertainties could affect the NPV values being compared. Table 6 shows the sensitivity analysis of green building LCC impact, at various discount rates (3.41%, 4.22%, 4.26%, 4.69 and 5.11%) and the effect of changing the life cycle of the buildings (40, 45, 50, 55 and 60 years respectively).

Table 6: Sensitivity Analysis with Changing Discount Rates and Life Cycle

Sensitivity Analysis	Parameter Change %	-20%	-10%	0%	10%	20%
Sensitivity Analysis Stage 1	Discount Rate	3.41%	4.22%	4.26%	4.69%	5.11%
	Life time of the building	50	50	50	50	50
	Green building LCC Impact	-30%	-30%	-28%	-27%	-28%
Sensitivity Analysis Stage 2	Discount Rate	4.26%	4.26%	4.26%	4.26%	4.26%
	Life time of the building	40	45	50	55	60
	Green building LCC Impact	-27%	-28%	-28%	-28%	-28%

The sensitivity analysis indicates that when the discount rates and life cycle vary ±10% or ±20%, the green building LCC impact varies 0-2% and varies 0-1% respectively. However, these changes in LCC are insignificant. This analysis further confirms the finding that the life cost of green building is 28% less than a similar type of conventional building.

5. CONCLUSIONS

In the Sri Lankan context, the industrial manufacturing buildings are at the forefront in terms of green certification. A total of 18 (out of 38) LEED certified green industrial buildings are in operation. However, are these buildings economically sustainable? It is not evident in the global or local context that how much a green industrial space costs and benefits over its life cycle. Previous studies suggest that the upfront cost concern is one of the main barriers which exist when deciding whether to execute a green building project (Hydes and Creech, 2000; Nelms, *et al*. 2005). Whereas some researchers argue that reasonable levels of sustainable design can be incorporated into most building types at little or no additional cost (Dwaikat and Ali, 2016).

On that note, a single case study approach was adopted where the life cycle cost of a green building and a similar natured conventional industrial building were compared. According to comparison, the life cycle cost of green building is 28% less than that of a conventional building while the green building offers a saving of 39% in terms of running cost. However, the initially cost attributed to green features are 28% higher than a similar type of conventional industrial building. This finding is of the similar view of Bombugala and Atputharajah (2010) who concluded that the construction cost of green buildings is 20-25% higher than traditional buildings in Sri Lanka. However, majority of the previous studies done in other countries reported that the green cost premium is between 0 to 10% while few studies explaining that the green building construction cost premium could be increased up to 20 or more than 20%. As a departing point of findings, this current study reports the status of green industrial buildings. According to findings green industrial buildings are economically sustainable with the overall saving of 28% achievable over its life time. It is expected that this study would enhance the green investors to take informed decision upfront and thereby contribute to achieve higher level of sustainability at large.

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