CARBON NEUTRAL DESIGN PROCESS TOWARDS SUSTAINABLE TOURISM ARCHITECTURE: *A case study of tourist accommodations in Ella*

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Abstract: The life cycle design process is a key determining factor of the Carbon Footprint (CF) of a building. The study explores the Carbon-Neutral Design Process (CNDP) as a life cycle design approach focusing on mitigating CF during the design process. CNDP suggests design strategies, recommendations, and interventions to reduce CF. Recognizing the tourism industry's significant carbon emission, environmental impact, and socio-cultural significance; the study aims to examine the level of integration of CNDP to mitigate CF in the tourism accommodation in Sri Lanka. The Ella tourism zone was selected as the context for the study. Due to its rapid tourism development and environmental impact. The research methodology involved developing a scorecard based on comprehensive literature mapping of the CNDP considerations. This developed scorecard was used to conduct a qualitative, comparative analysis of 4 selected cases. These 4 cases were chosen from a pool of 10 identified hotels within a 1.5 km radius of Ella urban center, ensuring a non-biased selection process. The findings indicate less concern for microclimate in the design phase and a lack of awareness of carbon emissions during the construction and operational phases. The case study buildings are evident for limited use of natural ventilation, renewable energy, and low-carbon construction materials. Thus, it highlights the importance of regional-level regulations for CF mitigation at neighborhood, site, and building scale to achieve sustainable tourism architecture.

Keywords: *Carbon-neutral design Process (CNDP), Life cycle design process, Carbon Footprint, Sustainable tourism architecture.*

1. Introduction

The life cycle design entails a holistic design approach that considers the environmental impact of the design throughout the entire life cycle of the design. The entire life cycle encompasses from extraction of raw materials, manufacturing, transportation, utilization, and recycling of materials back into the industrial process. (Jasch & Peneda, 1996). In the context of the construction of a building, this approach considers the building's relationship with its surroundings, technical components integrated, and incorporated tectonics as essential elements of a cohesive system addressing the entire life cycle of the building. (Larsson, 2005). Scholars argue that the life cycle carbon flow is significantly influenced by design decisions made within the design process. Therefore, the life cycle design process has gained crucial attention in deciding and determining the carbon footprint (CF) of a building.(Kuittinen et al., 2022)

1.1. CARBON FOORPRINT AND ACCOMADATION SECTOR

CF is defined as the total amount of carbon dioxide emission linked to the actions and operations of an individual or entity. These actions and operations encompass the level of buildings, cooperation, or country. (Selin, 2023) The study focuses on two industries that significantly contribute to global carbon emissions; tourism and construction. The tourism industry contributes a significant 10% of global CF while the construction industry is responsible for over 30% (Lenzen et al., 2018).

The accommodation sector of tourism lies between the intersection points of these two industries and showcases a critical attention must be gained. Therefore, the study intends to explore the accommodation sector of the tourism industry due to its significant contributions to carbon emissions. Also, it is considered the second largest contributor to carbon emissions in the tourism industry. (World Tourism Organization (UNWTO) & International Transport Forum, 2019). Moreover, carbon footprint-related studies on the accommodation sector in the South Asian region have gained insufficient attention(Koiwanit & Filimonau, 2021). It also highlights the need for the study.

1.2. LIFE CYCLE DESIGN PROCESS.

The CF of a building is determined by its various stages of the entire life cycle. Therefore, 40% of its CF is attributed to energy consumption, 25% to water usage, 30% to utilize material consumption, and 25% the waste generation. CF of a building is divided into two main categories: 1) embodied emission and 2) operational emission. (UNEP, 2020) (Abdelaal et al., 2022)

Emissions caused during the construction and end of the building life cycle are identified as embodied emissions. Emissions caused during the operational stage of a building's life cycle are defined as operational emissions.(Abdelaal et al., 2022).

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La Roche (2017) and (Kuittinen et al., 2022) highlight the need for a holistic design approach to mitigate CF in the life cycle of a building. The book "Carbon: A Field Manual for Building Designers" by La Roche advocates an argument that the life cycle carbon flow is significantly influenced by design decisions made within the design process. The **Carbon Conscious Design Process (CCDP**) and **Carbon Neutral Design Process (CNDP)** are two examples of foundational theories that focus on the life cycle design process to mitigate CF. These two approaches suggest design principles, design strategies, and recommendations.

Integration of the life cycle design process that aims for CF reduction and mitigation becomes a timely concern in sustainable tourism development. Thus, the study examines the integration of the life cycle design process into sustainable tourism development. It primarily adopts the Carbon Neutral Design Process (CNDP) as the main theoretical foundation of the life cycle design approach. For further research and ease of usability, the study has developed a literature mapping of CNDP with design strategies mentioned by La Roche (2017).

1.3. CARBON NEUTRAL DESIGN PROCESS (CNDP)

La Roche (2017) introduced the Carbon Neutral Design Process (CNDP) in his book 'Carbon-Neutral Architectural Design,' offering a comprehensive framework to minimize carbon emissions in the building industry and reduce anthropogenic greenhouse gas (GHG) emissions. CNDP primarily aims to mitigate the potential carbon emission of a building and bring its emissions in line with its carbon sink capacity. This status, where a building's emissions are equaled by its potential to offset them, is defined as a carbon-neutral building. (La Roche, 2017)

CNDP identifies diverse strategies to reduce emissions across various stages of the life cycle of a building. Consequently, La Roche has introduced a framework (Figure 1) for generating design strategies in CNDP. According to him, this framework could continue to be adapted, refined, and updated on a specific condition. Roche emphasized 4 major sources of emission in the life cycle of the building to develop the framework. 1)The operational phase 2) Construction phase 3) Water consumption 4) Waste generation. Based on these sources he suggested design strategies to utilize in different scales of the life cycle design process. Such as Regional and urban level to the site, building envelope, and building components.

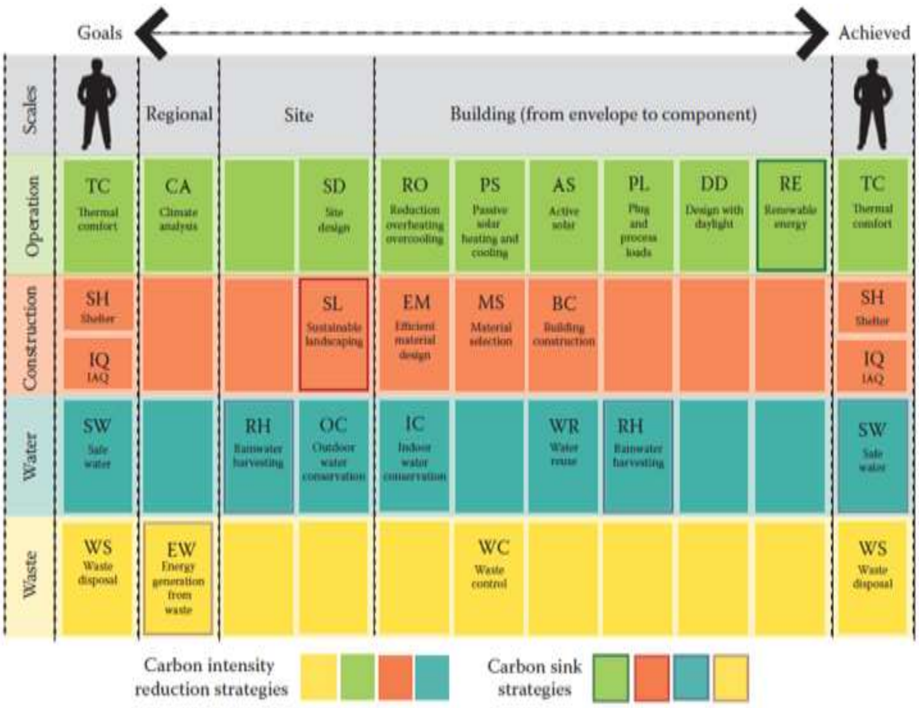

Figure 1, Carbon neutral design process framework (*La Roche,2017*)

The CNDP strategies are classified into two groups. It is based on their relevance in reducing carbon emission and promoting sequestration: A) Emission reduction Strategies and B) Carbon offsetting strategies "carbon sinks". Moreover, several goals and baseline requirements are outlined in this framework according to target sources of emission. Such as thermal comfort, shelter, Indoor air quality, Safe water, and waste disposal.

2. Research Methodology

The research aims to examine the effectiveness of CNDP design strategies integrated into the design process of tourist accommodation architecture in Sri Lanka. The research methodology was developed to assess the level of integration of CNDP consideration in current practices. Thus, A literature mapping of CNDP considerations has been conducted during the study as shown in Table 2. It was developed based on La Roche's (2017) studies. The research utilized a comparative case

study methodology. Therefore, the qualitative approach was adopted as the preferred methodology due to the nature of the data associated with CNDP design considerations in Figure 2.
The case study methodology consists of several stages.

A. Formulate case study assessment and examination criteria.
B. Selection of the cases.
C. Data collection and sampling of the data.
D. Analysis of the case studies individually and Comparative analysis.
E. Conclusion of the case study investigation.

Source	Scale	Major Design considerations for design strategies	Design strategies
Operation	Regional	Climate Analysis – CA	1. Climate design - CD
			2. Geographical distribution emission - GD
	Site	Site design – SD	3. Low-energy neighborhood design - LN
			4. Solar and Eolic site analysis – SE
	Building	Reduction of overheating and cooling – RO	5. Low energy envelope - LE
			6. Radiation impact on surfaces- RS
			7. Fenestration and shading - FS
		Passive solar heating and cooling – PS	8. Design for wind- DW
			9. Direct gain – DG
			10. Natural ventilation - NV
			11. Ambient air as a heat sink (Sensible components)
			12. Evaporative cooling
			13. Radiant cooling
			14. Earth coupling
		Active solar – AS	15. Solar hot water – SW
			16. Active heating - AH
		Plug and process load - PL	17. Plug and process load - PL
		Design with daylight – DD	18. Efficient daylight - ED
			19. Light shelves – LS
		Renewable energy – RE	20. Photovoltaic design – PV
			21. Bioreactor BR
Construction	Regional		
	Site	Sustainable landscape– SL	22. Vegetation as a sequester - VS
	Building	Efficient material design – EM	23. Modular design – MD
		Material selection – MS	24. Low carbon materials - LC
		Building construction – BC	25. Zero waste construction - ZW
Water	Regional		
	Site	Outdoor water conservation – OC	26. Native plants – NP
			27. Drip irrigation – DI
			28. Permeable hardscape - PM
	Building	Indoor water conservation – IC	29. Low flow fixtures – LF
			30. Dry fixtures - DF
		Water reuse – WR	31. Gray water reuse - GW
		Rainwater harvesting – RH	32. Rainwater Harvesting – RH
Waste	Regional	Energy generation from waste – EW	33. Generate energy from methane - MT
	Site	Waste control – WC	34. Composting – CM
	Building	Waste control – WC	35. Recycling – RC

(green)	Carbon sink strategies
(white)	Emission intensity reduction strategies

Figure 2. Literature mapping of CNDP Considerations based on La Roche's studies.

The assessment criteria are grounded in the developed literature mapping shown in Figure 2. Certain CNDP strategies were not considered due to the limitations and scope of the study. The inclusion criteria of the study are;1) All the CNDP recommendations and design strategies applied to the local climate conditions (Tropical hot-humid climate) are included. 2)Recommendation and design strategies required excessive time and data to analyze and were out of the scope of the study.

2.1. SELECTION OF THE CASES.

Sri Lanka Tourism Development Authority (SLTDA) master plan for 2020-2030 identified 7 different tourism zones with significant tourism growth. (Arugambay, Ella, Nuwara Eliya, Kalpitiya, Beruwala, Hikkaduwa, and Pinnawala). From these 7 areas, SLTDA has broad special concern on Ella and Arugambay and developed two master plans in collaboration with the UDA Sri Lanka. Therefore, Ella is identified as a focal point of tourism development in Sri Lanka.

UDA Tourism Development Master plan zoned areas of the Ella Tourism zone based on their contribution to tourism and land use. The Ella urban center has the highest influence on tourism. It is considered the main tourism service zone as shown in Figure 3. It consists of a higher number of tourist service providers and accommodations. The cases selected from this zone.

- A 1.5 km radius from the Ella city center is considered to select the potential cases. It indicates a similar contextual setup to the properties and factors regarding transport and accessibility as shown in Figure 3.
- Utilizing feedback and ratings on platforms like TripAdvisor, Booking.com, and Google Travel, a list of 10 tourist accommodations providers has been compiled. These are considered the trendsetters of the context. From the initial list, 4 cases were identified as shown in Table 1. It is based on the availability of data and permission for further research data collection.
- The typology of the tourist accommodation is not considered in the selection criteria. All cases are at the operational phase of their life cycle.

Table 1, Brief details of selected Cases

Case study		Identified typology	Area (sqm)	Description
Case (C1)	**1**	Resort and Spa	1500	A luxury resort developed during the early tourism boom in Ella, situated within a private tea estate. The focus is on the initial phase of development, including the resort, spa, pool, six-room categories, office facilities, reception, and car park. Displacement factor (km) from Passara junction - 1.5 km
Case (C2)	**2**	Resort	2400	Located near the Ella urban center, this resort is known for its stunning views of Ella Rock and Ella Gap, which enhance its appeal as a tourist destination. Evolving through multiple stages of development, the property has transformed from a conventional residential building into a hotel, reflecting its adaptation to growing tourist demand. Displacement factor (km) from Passara junction – 0.9 km
Case (C3)	**3**	Botique Hotel	423	Located near the Ella urban center, this luxury boutique hotel stands out for its unique design. the hotel was developed in a neighborhood with a haphazard layout, as noted by the architect. Displacement factor (km) from Passara junction – 0.3 km
Case (C4)	**4**	City Hotel	4500	The city hotel, located in the heart of Ella's urban center, The property, originally featuring a pre-existing hotel building, has undergone several construction and demolition phases. Different design stages have been implemented, with multiple designers involved in the overall transformation. Displacement factor (km) from Passara junction – 0.07km

Figure 3 The distribution of Cases and Ella tourist zone

2.2. DATA COLLECTION AND SAMPLING OF THE DATA.

Major data collection has been conducted as on-site observations to collect all necessary data for the study. Photographs of the implication and sketches were collected during on-site collection. Table 2 shows a summary of the collected data and method of the data collection.

Table 2, Brief details of data collection.

Data	Data collection method
1. Initial information on the design. **2. Concept and design approach.** **3. Data related to the CNDP considerations** **4. Other information about the project and significant areas** **5. Plans, sections, elevations, and other technical data of the designs.** **6. Photographs of the cases.** **7. Feedback from the client and users, previous research and studies, public attention to the project awards won by the project, etc.**	**1. Several on-site observations have been conducted in all cases. A photographic study and on-site data collection based on the criteria were conducted.** **2. Conducted several open-ended interviews with the designers and design teams based on the assess and examine criteria.** **3. Interviews with the owners, staff, and workers of the property** **4. Previous research and studies.** **5. Public critiques and feedback on the projects.** **6. Judgment and awards for the projects.** **7. Photo collections are available on online platforms.** **8. Other media platforms, visual programs on websites, and mass media.**

2.3. DATA ANALYSIS AND EVALUATION.

The study consists of two analysis methods. 1) **Data analysis of the individual cases**: Examine criteria consist of a larger number of qualitative factors, as the first step data has been analyzed individually (Case basis method) with the same examination criteria. The rating method was used to measure the applicability of the design considerations. At the end of each rationale of the low carbon design strategies framework and each consideration of the pre-design recommendations descriptive analysis was conducted to analyze the qualitative factors. 2)**Data analysis of all cases as a comparative analysis**: A comprehensive examination of data was conducted to achieve a well-rounded understanding of the integration of low-carbon design considerations. Case studies were juxtaposed and assessed, and both favorable and unfavorable aspects were examined and evaluated comparatively.

3. Analysis and Results

The assessment criteria were formulated to assess and examine the integration of CNDP consideration based on the four emission sources (operational, construction, water, and waste) identified in the framework for CNDP. The evaluation and analysis of the data is a combination of both qualitative description and comments on the integration of the low carbon consideration and quantitative rating system which indicate the level of applicability of the consideration. This rating method categorizes achievement levels as follows: Excellent (75-100%), Good (50-75%), Moderate(25-50%), Poor (0-25%), and Not Relevant/Not used (0%). Also, The classes are converted into numerical values for visualization as follows: Not relevant/Not used = 0, Poor = 1, Moderate = 2, Good = 3, and Excellent = 4. All cases were assessed in detail individually in the first round. The comparative analysis conducted in the second round and a summary of each focused area are discussed below based on considered emission sources;

3.1. INTEGRATION OF CNDP CONSIDERATIONS (REGIONAL AND SITE SCALE) – OPERATIONAL PHASE

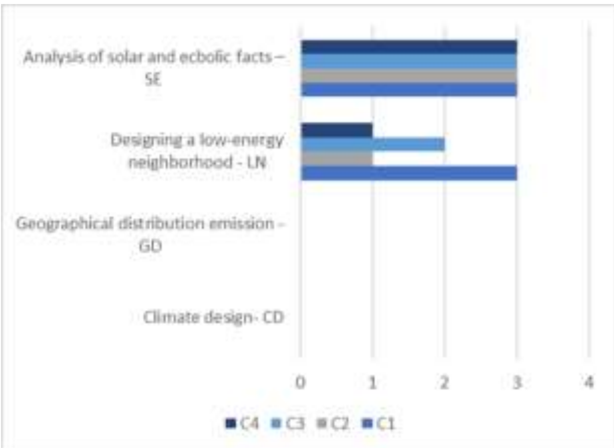

Figure 5 Level of integration of CNDP strategies(Reginal and site scale) - Operational phase

As shown in Table 3, consideration of local climate conditions data and thermal comfort data for generating design strategies gained insufficient attention in some cases. Insufficient attention has been given to the geographical emission distribution data. The study suggests mapping and investigation of the contextual emission data will aid in creating low-carbon strategies in the future. Both cases 2 and 4 inadequately addressed cross ventilation at the neighborhood level. These cases act as wind barriers at the neighborhood scale. Case 3's strategies implemented to improve cross ventilation across the neighborhood level are commendable. Every case has analyzed solar factors and designed shaded spaces sufficiently.

Table 3, Comparative Case Study Assessment Summary 1

Case Study Assessment and Examination Criteria for CNDP Considerations (Reginal and site scale) – Operational Phase							
Source of emission	Scale	Main consideration	Main design strategies	C1	C2	C3	C4
1) Operational emission	Regional	Climate Analysis – CA	Climate design- CD	○	○	○	○
			Geographical distribution emission - GD	○	○	○	○
	Site	Site design – SD	Designing a low-energy neighborhood - LN	◕	◔	◒	◔
			Analysis of solar and ecbolic facts – SE	◕	◕	◕	◕
(Not relevant/Not used-○, Poor-◔, Moderate-◒, Good-◕, Excellent-●)							

3.2 INTEGRATION OF CNDP CONSIDERATIONS (BUILDING SCALE) – OPERATIONAL PHASE

Table 4, Comparative Case Study Assessment Summary 2

Case Study Assessment and Examination Criteria for CNDP Considerations (Building scale) – Operational Phase							
Source of emission	Scale	Main consideration	Main design strategies	C1	C2	C3	C4
1) Operational emission	Building	Reduction of overheating and cooling – RO	Low energy envelope - LE	◒	◔	◒	◔
			Radiation impact on surfaces- RS	◒	◔	◕	◒
			Fenestration and shading - FS	◒	◒	◒	◒
		Passive solar heating and cooling – PS	Design for wind- DW	◕	◒	◕	◒
			Natural ventilation - NV	◒	◔	◒	◔
		Active solar – AS	Solar hot water – SW	●	●	●	●
		Plug and process load - PL.	Plug and process load - PL.	○	○	○	○
		Design with daylight – DD	Design with daylight – DD	◕	◕	◕	◕
		Renewable energy – RE	Photovoltaic design – PV	○	○	○	○
(Not relevant/Not used-○, Poor-◔, Moderate-◒, Good-◕, Excellent-●)							

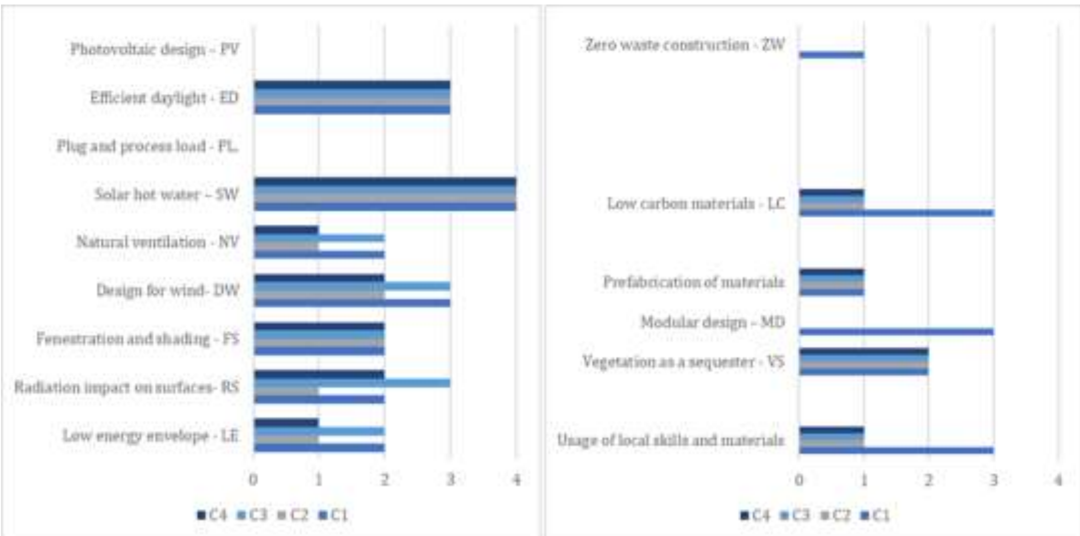

Figure 6 A) Level of integration of CNDP strategies(Building scale) - Operational phase, B) Level of integration of CNDP strategies - Construction phase

As shown in Table 4, In cases 2 and 4 given the lack of focus on reduction of overheating and cooling, insufficient additional shading for solar exposed surface received direct solar heat gain due to the building orientation. Case 1 utilized moderate design strategies while Case 3 focused on thoughtful design. All cases have moderate consideration of passive heating and cooling. Design strategies utilized in Cases 1,2 and 4 do not promote cross ventilation. But case 3 utilized a commendable level of design strategies to get natural ventilation. Night ventilation, stack ventilation, and other wind design strategies are not considered in these cases. (Table 4) All cases utilized solar hot water systems. Daylight optimization was attempted in all cases, but cases 2 and 4 had insufficient levels in some volumes. Consideration of renewable energy was not considered. Case 2,3,4 have solar-ready roofs in contrast to case 1 non-supportive roof design. (Figure 6)

3.3 INTEGRATION OF CNDP CONSIDERATIONS - CONSTRUCTION PHASE

Table 5, Comparative Case Study Assessment Summary 3

Case Study Assessment and Examination Criteria for CNDP Considerations – Construction Phase							
Source of emission	Scale	Main consideration	Main design strategies	C1	C2	C3	C4
2) Construction phase	Reg		Usage of local skills and materials	◕	◔	◔	◔
	Site	Sustainable landscape– SL	Vegetation as a sequester - VS	◒	◒	◒	◒
	Building	Efficient material design – EM	Modular design – MD	◕	○	○	○
			Prefabrication of materials	◔	◔	◔	◔
		Material selection – MS	Low carbon materials - LC	◕	◔	◔	◔
		Building construction – BC	Zero waste construction - ZW	◔	○	○	○
(Not relevant/Not used-○, Poor-◔, Moderate-◒, Good-◕, Excellent-●)							

Case 1 has commendable consideration of local skills and materials; other cases show moderate incorporation of local skills and materials. As shown in Table 5, all cases have moderate consideration of sustainable landscape design with case 3 being particularly commendable. Only case 1 has considered the modular design approach for the reduction of construction complexities and waste generation. Consideration of pre-fab materials is insufficient, while all cases utilized moderate levels of semi-pre-fab materials. However, Case 2,3,4 indicates inadequate consideration of low-carbon material selection, with minimal consideration of reused, recycled, and locally available materials. Consideration of reused materials and local materials in Case 1 is commendable. Especially for the roof design. All cases were not considered zero waste construction. (Figure 6) Due to the trends and competition in the tourism market design teams often utilize material extensive approaches and outsource main construction teams and materials which leads to higher emissions of material transportation.

3.4 INTEGRATION OF CNDP CONSIDERATIONS – WATER CONSUMPTION

In all cases, the incorporation of native plants to optimize outdoor water conservation was observed at a moderate level. The landscape design of the Case 3 indicates thoughtful design. Drip irrigation and permeable landscape gained an insufficient consideration. Indoor water conservation approaches, re-usage of water, and rainwater harvesting gained insufficient attention in all cases. (Figure 6)

Table 6, Comparative Case Study Assessment Summary 4

Case Study Assessment and Examination Criteria for CNDP Considerations – Water Consumption							
Source of emission	Scale	Main consideration	Main design strategies	C1	C2	C3	C4
Water	Site	Outdoor water conservation – OC	Native plants – NP	◔	◒	◒	◒
			Drip irrigation – DI	○	○	○	○
			Permeable hardscape - PM	○	○	○	○
	Building	Indoor water conservation – IC	Low flow fixtures – LF	○	○	○	○
			Dry fixtures - DF	○	○	○	○
		Water reuse – WR	Gray water reuse - GW	○	○	○	○
			Black water reuse- BW	○	○	○	○
		Rainwater harvesting – RH	Rainwater Harvesting – RH	○	○	○	○
Not relevant/Not used-○, Poor-◔, Moderate-◒, Good-◕, Excellent-●)							

3.5 INTEGRATION OF CNDP CONSIDERATIONS – WASTE GENERATION

The absence of regional-level innovative waste management protocols is identified. Typically, In all cases, the collected waste is dumped in an open site by a regional-level mechanism. However inadequate attention was gained to proper waste management mechanisms at the regional level. As shown in Table 7, all cases have taken inadequate design approaches to mitigate the emission related to waste on site and building scale. (Figure 7)

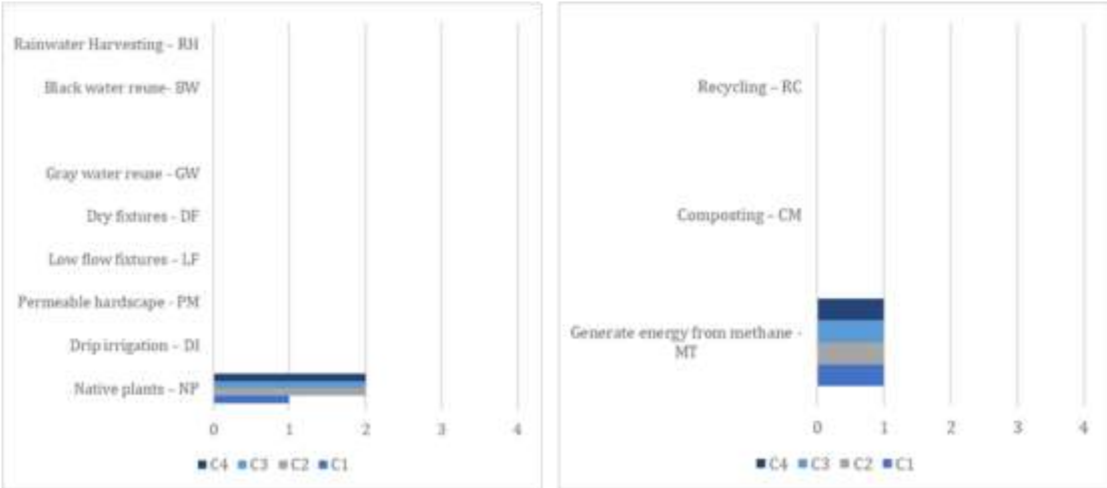

Figure 7 A) Level of integration of CNDP strategies – Water consumption, B) Level of integration of CNDP strategies - Waste generation

Table 7, Comparative Case Study Assessment Summary 5

Case Study Assessment and Examination Criteria for CNDP Considerations – Waste Generation							
Source of emission	Scale	Main consideration	Main design strategies	C1	C2	C3	C4
Waste	Regional	Energy generation from waste – EW	Generate energy from methane - MT	◔	◔	◔	◔
	Site	Waste control – WC	Composting – CM	○	○	○	○
	Building	Waste control – WC	Recycling – RC	○	○	○	○
(Not relevant/Not used-○, Poor-◔, Moderate-◒, Good-◕, Excellent-●)							

4. Discussion and Conclusion

The study reveals crucial insights into design practices and areas that need improvements for achieving carbon neutrality. Even though the climate conditions of Ella present opportunities for energy-efficient design. The surveyed cases indicate insufficient design consideration of climate-responsive design strategies. Most of the cases have inadequately considered the local climate conditions. Integration of natural ventilation strategies especially cross ventilation, and incorporation of renewable energy sources at the neighborhood level are inadequately addressed. Notably, Case 3 has showcased thoughtfully adopted passive cooling strategies on the site scale.

The comparative analysis demarcates that the incorporation of low-carbon design strategies on the site scale and building scale is insufficient. Inadequate shading strategies and, a lack of approaches to achieve cross-ventilation have been identified in building scale. The dependency on conventional construction materials that have a higher carbon footprint, and lack of selection of recycled, re-used materials and locally sourced alternative materials were common in most of the cases. It emphasizes the need for regional-level regulations and a more comprehensive design framework to regulate the embodied emissions and emissions during the other phases of the design which improves the sustainability of the life cycle of the building.

Furthermore, the study emphasizes the need for effective strategies for waste management and water conservation due to the absence of advanced waste management protocols and water conservation measures. Therefore, it suggests the integration of innovative design implications for waste reduction approaches such as zero waste construction and advanced water reuse mechanisms parallel to the carbon-neutral design.

Even though some cases have commendable utilization of some CNDP strategies, overall findings emphasize limited integration of CNDP strategies in all cases. Therefore, it highlights a crucial need for the incorporation of CNDP strategies into current practices of the accommodation sector. The study strongly emphasizes the importance of considering regional climate conditions, regional emission levels, microclimatic factors, and the use of low-carbon materials, and focuses on the building's entire life cycle throughout the design process. Strengthening these areas of the accommodation sector will be more beneficial for the tourism industry in Ella and similar contexts. Further, it will contribute to creating a resilient and environmentally responsible tourism sector

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