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An Investigation Into Adoption of Green Measures Within Green Building Rating Programs For Affordable Housing In India

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Highlights

- Green Affordable Housing (GAH) project's sustainability is expressed using four Key Parameters: Climate Response, Climate Resilience, Gender Sensitivity, and Affordability.
- Relationships between prevailing Green Building Rating Programs' (GBRP) criteria and Key Parameters explored.
- Insights into the on-ground execution of GBRP criteria gathered from Green Building Rating Agencies and Consultants.
- Gaps in the prevailing GBRPs were identified.
- Suggestions are made to prevailing GBRPs to enhance their future relevance.

Abstract

Resource-efficient buildings conducive to occupants' health and well-being are termed Green Buildings (GB). Dedicated organizations, called Green Building Rating Agencies (GBRA), are involved in formulating Green Building Rating Programs (GBRP). The GBRPs feature predetermined, intent-based Rating Criteria (RC). Their rating mechanism is based on a relative comparison between the building's base-case and Green-iteration, apathetic to its absolute operational performance.

This study identified four Key Parameters: Affordability, Gender Sensitivity, Climate Response, and Climate Resilience, representing a Green Affordable Housing (GAH) project's holistic – Financial, Social, and Environmental – sustainability. GBRPs were studied to gauge whether and to what extent the RC embodies the Key Parameters. Concurrently, inputs regarding the on-ground execution of GBRPs were gathered from GBRA and Consultants. This study illuminates the gaps in the prevailing GBRPs and makes suggestions to maintain their future relevance. It concludes with the requirement of a rating framework anchored to absolute design baselines and operational performance benchmarks.

Keywords: Green Building Rating Programs; Green Affordable Housing; Climate Resilience; Adaptation; Holistic Sustainability

Introduction

Humans' ever-increasing desire for fast-paced progress has led us to rely heavily on fossil fuel-based mechanical and economic systems, resulting in incessantly increasing carbon emissions, global warming, and climate change. The continual rising of the earth's surface temperatures, disruption of natural weather patterns, and extreme weather events such as heatwaves, flash floods, cyclones, wildfires, droughts, etc., are manifestations of climate change [1]–[5]. These events are predicted to worsen consistently in the coming years, having already resulted in the loss of more than 2 million lives and USD 4.3 trillion in the last five decades [6]. Countervailing efforts to mitigate and adapt to the aggravating climate change scenario are bound to impact individuals, communities, and industries alike.

Construction is the world's biggest industry, constituting thirteen percent of the global Gross Domestic Product (GDP) [7]. On the one hand, the construction industry is responsible for more than one-third of global carbon emissions [8]. On the other hand, it is severely vulnerable to extreme weather events. Such events would not only physically distress the building's construction workers and occupants but also endanger its asset value. Confronted by these consequences, the construction industry, including all products and processes, is currently exploring decarbonization pathways to develop in a sustainable and secure manner. One such market initiative to propel sustainability was Green Buildings (GB). By definition, these are buildings planned, designed, constructed, and operated in a manner that consumes fewer resources, is energy efficient, and is conducive to occupants' health, comfort, and well-being [9]. Dedicated organizations, called Green Building Rating Agencies (GBRA), are currently in place at national- and international levels. Their primary functions include a) formulating Green Building Rating Programs (GBRP) applicable nationally or internationally, tailored to various building typologies, and b) awarding a building 'Green' certification by examining whether it has been designed and constructed as per the GBRPs. Essentially, GBRPs encompass Rating Criteria (RC) that deal with optimizing design, resource use, and construction practices. Another set of organizations involved in the on-ground implementation of GBRPs are Green Building Rating Consultants (GBRC); they play a pivotal role in ensuring the building is executed per the GBRP's requirements.

GBs are treated as a pinnacle in the built environment. They are often sold or rented at a premium, although their incremental development cost in comparison to conventional buildings may be reasonably small [10]. GBs also have significantly lower operational costs. However, their higher upfront cost makes them unaffordable, thus making them inaccessible to the Economically Weaker Section (EWS) and the Lower Income Group (LIG). These groups of people are the most vulnerable to the ill effects of climate change, making it all the more important for them to have access to sustainable residences that are resilient to extreme weather events. Notably, a vast demand-supply gap already exists globally in the affordable housing market. With more than half of the world's population dwelling in cities in 2022 [11], governments worldwide have been struggling to bridge the affordable housing gap. Developing sustainable/Green residences amidst the looming climate change threat is yet another challenge. Green and Affordable Housing (GAH) is the means to overcome these two challenges and unify their intents.

Countries have developed GAH projects under their social and/or affordable housing programmes [12]. India, too, is developing affordable housing through a pipeline of several central and state-level schemes. Notably, the Pradhan Mantri Awas Yojana (PMAY) scheme has contributed to both affordability and sustainability. Alongside developing affordable housing, the scheme has prioritized occupant comfort by incorporating new and alternative construction materials, technologies, and passive design features [13]–[15]. Furthermore, the development of 'adequate, safe, and affordable housing' is one of the United Nation's seventeen Sustainable Development Goals (SDGs); it can further give impetus to other goals, such as 'clean and affordable energy,' 'gender equality,' and 'responsible consumption and production,' unlocking development and social equality [16]. In the context of a GB, 'sustainability' has conventionally referred to Environmental Sustainability; however, in a GAH project, it has a broader meaning. Housing is at the confluence of multiple domains; it is required to provide its occupants with the physical infrastructure/shelter while simultaneously satisfying their social and economic aspirations. Therefore, the GAH framework adopts a holistic outlook of sustainability, which may be seen as a three-tiered pyramid, wherein no one tier is compromised for the other. The types of sustainabilities and their corresponding implications for a GAH project are described in Figure 1.

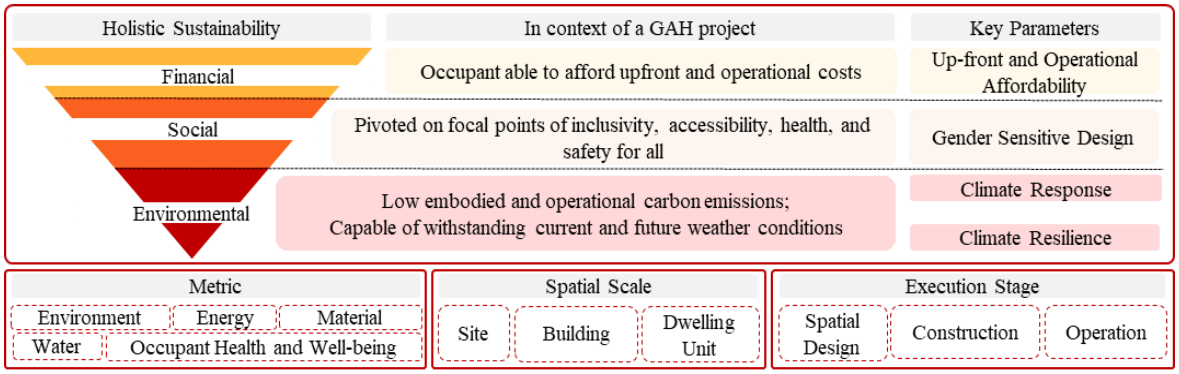


Figure 1: Pyramid of Sustainability and the Four Key Parameters

The first tier – Financial Sustainability – unlocks the means for a person of a weaker economic background to **afford** a Green residence. How affordable a product/service is is one of the primary factors determining its feasibility from the user's perspective, thus their likeliness of choosing it. Therefore, demonstrating Financial Sustainability is the first and foremost step to unlocking market demand for GAH. The second tier – Social Sustainability – acknowledges the integral social needs of the individuals and communities residing in the housing project. **Sensitivity** to the nuanced ways people of varying backgrounds perceive and use the space is at the core of rendering a socially sustainable GAH project. A

gender-sensitive lens could do an excellent job of capturing the occupants' distinct contexts and satisfying their needs of inclusivity, safety, health, and well-being through design, construction, and operation. The third tier ensures that the project is environmentally sustainable, requiring the project to be: a) Planned, constructed, and operated resource-efficiently, principled to **respond** to the climatic context – reducing the project's carbon emissions, and b) **Resilient** to the present and future environment/climate and extreme weather events while maintaining a comfortable indoor environment for the users. For this study, the broader core intent of each of the sustainability tiers have been moulded into suitable Key Parameters, namely, Affordability, Gender Sensitivity, Climate Response, and Climate Resilience, shown in Figure 1. Their definitions have been elaborated in Table 1.

These parameters can explicitly communicate the underlying measure to achieve each sustainability tier; they are specific and may be quantified with the help of checklists and/or metrics. The following points shall help the reader gain insight into the author's thought process behind selecting each Key Parameter and their significance from the perspective of affordable housing:

Table 1: Key Parameters and Definitions

Key Parameter	Definition
Climate Response	Defined in terms of how a person, household, community, organization, or state acts in response to climate change. Their response would involve responding to the climate change already in the pipeline, ***reducing emissions***, and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere [1].
Climate Resilience	Defined as the ability of social, economic, and environmental systems ***to cope with a hazardous event***, trend, or disturbance. This would involve responding or reorganizing in ways that maintain their essential function, identity, and structure while also maintaining the capacity for learning and transformation [1]. The "hazardous events" for the scope of this study have been limited to heatwaves and floods – since India is a tropical country and more susceptible to the said events.
Affordability	Generally defined with regards to unit size and cost, occupant's income, and the unit cost-to-income ratio. This study adopts the PMAY guidelines' definition of affordable housing, mentioned below [17]: Unit size: The carpet area of Dwelling Units is required to be up to 30 m^2 for the EWS category and up to 60 m^2 for the LIG category. Occupant's Income: The qualifying annual household income for the EWS is set as INR 0.3 million, and for the LIG, the corresponding value is between INR 0.3 million and INR 0.6 million. This study simply appeals that the upfront and maintenance costs be affordable for the occupant; however, the study does not want to prescribe a specific – absolute or percentage – value to affordability. The GBRPs are free to adopt a befitting value in terms of GB's incremental development cost, unit-to-income ratio, and so on.
Gender Sensitivity	Refers to the ability to acknowledge and highlight the existing gender differences and inequalities between women and men. It guarantees that such ***differences are factored into the design*** and implementation of policies and actions [18]. It is an approach of holistic planning of the built environment, manifesting as but not limited to: • Conscious selection of the GAH site: ensuring proximity to social and public infrastructure. • Appropriate spatial planning: incorporating parks, recreational, entrepreneurial activities, and social gathering spaces. • Dwelling Unit being designed to adapt to occupants' evolving spatial and social needs. • Dwelling Unit being solely or jointly owned by the household's women.

- Affordability: A project would be financially sustainable if it is affordable on an upfront- and operational basis, in line with the definition of affordability.
- Gender Sensitivity: Gender Sensitive design principles pay careful attention to aspects of safety, health and comfort, and inclusivity at all spatial scales. These aspects are equally relevant to and affect all residents. However, females, children, and the elderly spend more time indoors than their male counterparts; hence, the appropriate fulfillment of these aspects would hold relatively higher importance for the former group. Integrating a gender-sensitive design lens would illuminate the challenges women face in the parlance of affordable housing and overcome them by including women as critical stakeholders in the decision-making process.
- Climate Response: A project's local climatic and geographic context provide crucial clues for its design. When used wisely, these clues may enlighten passive design strategies and locally available materials, which could facilitate maintaining a comfortable indoor environment, naturally, without using energy frivolous Air Conditioning (AC) systems. Hence, responding to the climate would lead to a reduction in the operational and embodied carbon emissions of the project.
- Climate Resilience: Over time, a project would be faced with extreme weather events such as heatwaves and floods. Designing with resilience in mind would ensure that the project infrastructure is physically capable of withstanding such events, simultaneously maintaining a comfortable indoor environment for its users. Notably, achieving a comfortable indoor environment without increasing the economic burden on occupants makes the four Key parameter *tenets* of a successful GAH project.

The study has contextualized the Key Parameters' conceptual definitions in terms of physically implementable measures, such that the intent behind the Key Parameters is met. As mentioned in Figure 1, the measures may be applicable at various 'Spatial Scales,' i.e., the entire project (*Site*), one building block (*Building*), and one residence (*Dwelling Unit*), and incorporated during the *Design*, *Construction*, and/or *Operation* 'Execution Stages' of the project. These measures may be in terms of design optimization and integration of components; their efficacy may easily be assessed in terms of 'Metrics,' i.e., resources – by examining a change in their consumption. For instance, Climate Response measures would be (a) using finishes with a high Solar Reflective Index (SRI) – at *Site*-scale, (b) using appropriate walling material having low thermal transmittance value – at *the building* scale, and (c) designing for optimized ventilation – at *Dwelling Unit*-scale.

This study assesses prevailing GBRPs from the perspective of the four key parameters and provides suggestions to maintain their future relevance in the parlance of GAH. The study's objectives included conducting a detailed study of the prevailing GBRPs, understanding whether and the extent to which the RC embodied the Key Parameters, and studying the current market trends concerning GBRP execution by conducting surveys with GBRA and GBRC.

Methods

This study's first stage involved a detailed review of the following GBRPs: The Green Affordable Housing Rating Program from the Indian Green Building Council (IGBC), the Green Rating for Integrated Habitat Assessment (GRIHA), and the Sustainability Certification from the Green and Eco-friendly Movement (GEM) and Excellence in Design for Greater Efficiencies (EDGE) [19]–[22]. The authors selected these GBRPs solely based on their availability in India; this study treats all these GBRPs as independent entities, not comparing them against each other. All GBRPs mentioned above are voluntary compliance-based, encompassing RC related to optimizing the following Aspects: Site, Energy, Environment, Water, Waste, Material, and on-site Practices. While the IGBC and GRIHA have a dedicated GBRP for affordable housing, the GEM and EDGE GBRP apply to all residential, commercial, and factory buildings alike. The Green Affordable Housing Program from the IGBC is a 75-credit-based program, requiring a minimum of 38 credits for certification, with four certification levels, namely – Certified, Silver, Gold, and Platinum; the GBRP from GRIHA is a 100-credit-based system, requiring a minimum of 25 credits for certification, with one-to-five-star certification levels. Similarly, the Sustainability Certification from GEM is a 135-credit-based system, requiring at least 40 credits for certification, with Gem 1 to Gem 5 certification levels. However, the EDGE GBRP is not a point-based system; it calculates the certification level with respect to the project's savings in water, material, and energy. Here, the project would receive a Level 1 certification by achieving 20% savings in water and material. Moreover, the project could receive a Level 2 or Level 3 certification based on the additional savings achieved in energy, i.e., 40% for Level 2 and 100% for Level 3.

Detailed study of the GBRPs led to categorizing the RC into 'Aspects,' 'Variables,' and 'Attributes.' Here, Aspects refer to the overarching domain addressed by the RC, Variables refer to the sub-domain-level strategies, and Attributes refer to the detailed micro-level measures required to achieve compliance. The elaborate list of Aspects, Variables, and Attributes can be found in Figure 3. After that, the relationships between the RC and the Key Parameters were assessed to understand whether and to what extent did the GBRPs embody the latter. Firstly, the one-on-one relationships between the Attributes and the Key Parameters were assessed; the resultant relationship between an Aspect and Key Parameter was derived by averaging the relationship scores of all Attributes of that particular Aspect. The relationship score was marked on a scale of 0 to 2, where 0 indicated 'No Relationship,' 1 indicated an 'Indirect Relationship,' and 2 indicated a 'Direct Relationship;' it was assigned based on the degree of explicitness of the Attribute's connection with the Key Parameter. The relationship scores were marked by building science researchers and GB professionals with a background in architecture, civil, and mechanical engineering, a post-graduate degree, and four years' worth of work experience in the construction industry. The following set of questions was framed to help the building science researchers and GB professionals assign relationship scores:

a) Affordability: Does the Attribute impact the project's upfront and operational costs?
b) Gender Sensitivity: Does the Attribute contribute to acknowledging and satisfying the needs of various occupant categories?
c) Climate Response: Does the Attribute impact the project's carbon emissions?
d) Climate Resilience: Does the Attribute impact the project's ability to withstand heatwaves and floods? How would the Attribute help maintain a comfortable indoor environment?
e) An additional question was posed to help understand the explicitness/directness of the relationship: Can the link between the Attribute and Key Parameter be described as a one-step cause-effect dynamic?

Essentially, the relationship only represents the magnitude of correlation and not its direction – positive or negative. For instance, the relationship score between the 'On-site Renewable Energy' Attribute and Climate Resilience is 1.67, implying that they are directly connected. However, the relationship score does not indicate whether the Attribute improves or impairs the project's Climate Resilience.

The study's second stage involved gathering insights from the organizations engaged in the implementation of GBRPs, namely, GBRA and GBRC. Communication with the high-level officials of the leading GBRAs was established via emails, requesting information regarding the total number of GBs and GAH projects developed in the past five years, their locations, and the most commonly and rarely attempted RC by project proponents. The project location-related data was then superimposed against the following:

a) ***The State Energy Efficiency (EE) Index*** is a measure of an Indian state's readiness concerning energy efficiency [23]. This study desired to 1) test the relationship between a state's EE Index and its available resources to make improvements in affordable housing and 2) perceive whether the projects were only found to be present in those cities having a higher EE Index.
b) ***Net State Domestic Product (NSDP) per capita*** is a measure of the net value of finished goods and services of the state per capita. The NSDP per capita of 2021, for this analysis, was obtained from [24].
c) ***Climate zone*** – The National Building Code (NBC) 2016 [25] divides India into five climatic zones; classifying project locations per their respective climate zones would help determine whether projects are consolidated in a particular climate zone. Subsequently, this classification could also highlight whether there is a climate zone-based trend to achieving ratings within a tight budget.
d) ***Heatwave and Flood Vulnerability zones*** - A project's disaster vulnerability depends on location. Thus, Climate Resilience measures would also be determined with respect to the project's location. Here, the project locations have been superimposed on heatwave [26] and flood vulnerability [27] maps.

Furthermore, dedicated online survey forms were shared with thirteen – large-scale as well as independent – GBRCs requesting information concerning the GB project proponents' most commonly and rarely executed RC. The GBRCs were also asked to rank the Aspects – 'Site Selection,' 'Energy Conservation,' 'Water Conservation,' 'Material,' and 'Environmental Quality' on five-point scales representing their technical and financial feasibility.

Notably, the group of building science researchers and GB professionals involved in assigning Attribute and Key Parameter relationships was separate from the GBRAs and GBRCs.

Results and Observations

The RC in the IGBC, GRIHA, and GEM GBRPs provide detailed instructions about the method/means to be followed to achieve the credits, while the RC in the EDGE GBRP delineates the performance goal to be achieved. All studied GBRPs are pivoted on demonstrating a relative improvement between a project's base-case – one which has no regard for sustainability whatsoever, and its Green-iteration – one which has incorporated green measures. Owing to a difference in the RC nature, this study has presented the assessment of the three GBRPs: IGBC, GRIHA, and GEM. Figure 2 illustrates the credits allocated to different Aspects by various GBRPs.

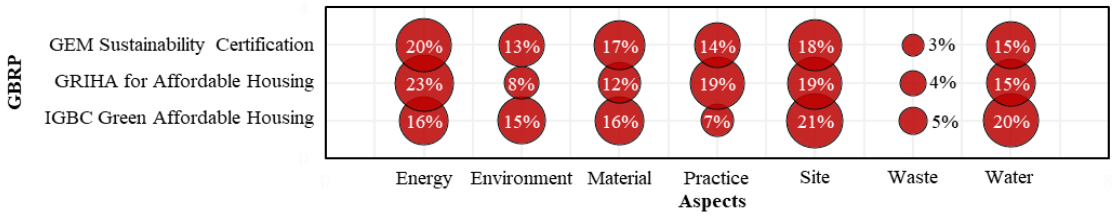


Figure 2: GBRPs and credit distribution as per Aspects

Interrelationship between the RC and Key Parameters

Figure 3 illustrates the relationship between the RC and Key Parameters. The Aspects, their corresponding Variables, and Attributes have been mentioned on the left; the individual one-on-one relationships between the Attributes and the Key Parameters have been averaged and presented as a 'Resultant' relationship between the Aspects and the Key Parameters.

The following observations can be made based on Figure 3:

- ***Affordability*** is strongly related to the 'Energy' Aspect. This is because of Attributes influencing GB's operational affordability, namely – "Incorporation of BEE 5-star rated equipment" and "Provision of on-site renewables." Figure 3 highlights that the 'Environmental' related Attributes – "Ventilation," "Daylight," and "Air quality concerns" – that have the most substantial influence on affordability are a function of window design and operation. Moreover, almost all the 'Material' related Attributes show direct relationships with affordability. Notably, the decisions concerning a) the design and functioning of windows and b) the selection of walling and roofing material are Design-stage inputs. These inputs continue to influence the GB's Affordability during the Construction-stage and Operation-stage.
- ***Gender Sensitivity*** is not directly related to any of the Aspects at the macro level. However, only a few Attributes directly related to Gender Sensitivity, namely – "Adaptive Comfort, Daylight," and "Ventilation," concern spatial

design. The rest of the Attributes directly related to Gender Sensitivity concern the provision of facilities. Moreover, the Attribute of "Access to clean sources of cooking fuel," which has a strong relationship with Gender Sensitivity, was only found in one of the GBRPs [20], surprisingly, not as a mandatory requirement.

- ***Climate Resilience*** is, essentially, the project's capacity to withstand events like heatwaves and floods. Now, the RC can only help equip the building to resist extreme heat and/or drain overflowing flood water but not directly cause the building to be immune to heatwaves and/or floods. Evidently, none of the Attributes would have a direct relationship with Climate Resilience.
- ***Climate Response*** is influenced directly by the 'Energy' and 'Site' Aspects and indirectly by the 'Environment,' 'Material,' and 'Practice' Aspects. The 'Site' and 'Environment' related Attributes deal with Climate Response by employing design strategies according to the local climate, thus reducing the indoor heat gain and mechanical cooling demand. In contrast, the 'Energy' related Attributes employ energy-efficient devices to achieve a reduction in energy consumption. Ultimately, both the design strategies and energy-efficient devices lead to a reduction in operational carbon emissions. Furthermore, the 'Material' and 'Practice' related Attributes contribute to Climate Response by targeting the reduction of embodied carbon emissions. This can be achieved by deploying innovative construction technologies and using materials with recycled content. Additionally, handling – reducing, and recycling – construction waste could significantly reduce the burden on virgin resources while neutralizing their contribution to embodied carbon emissions.

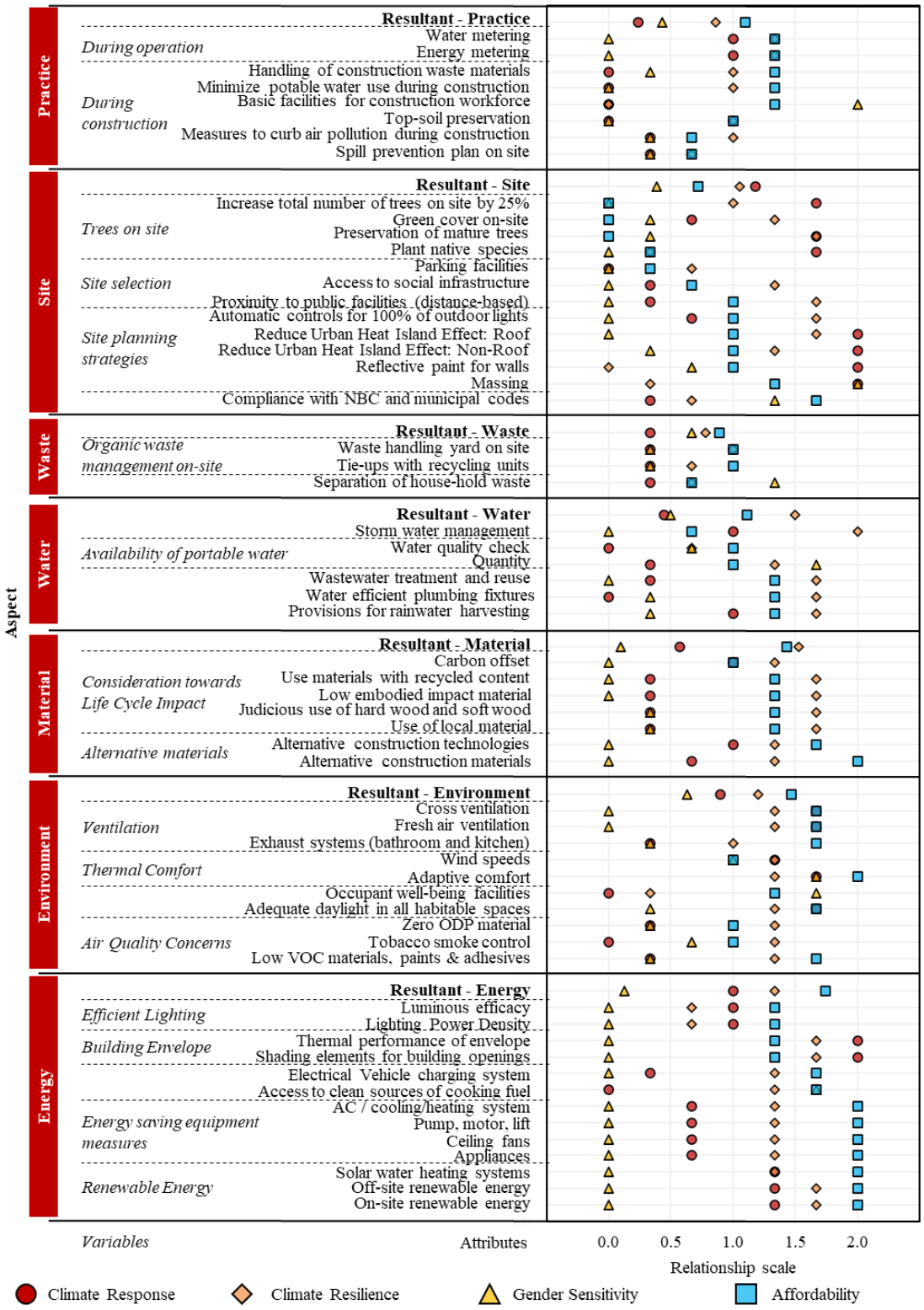
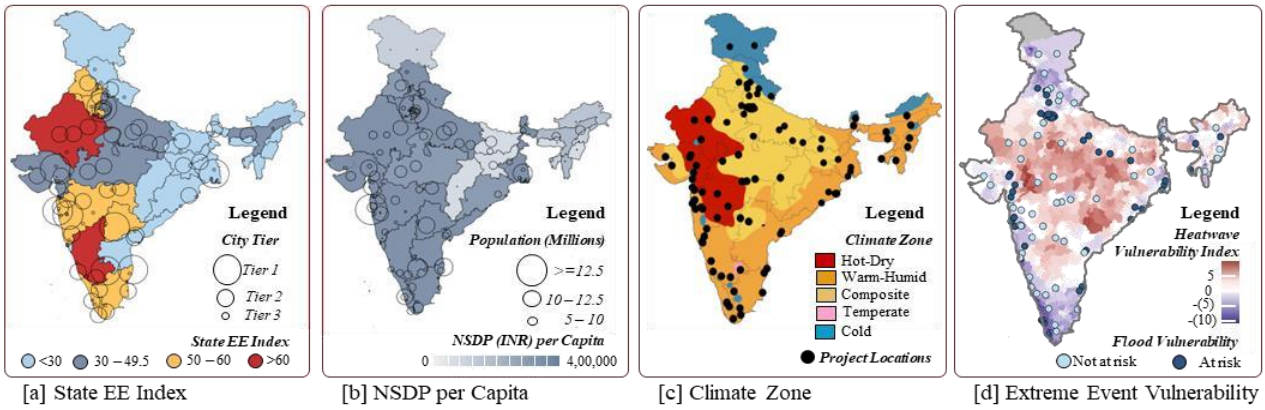


Figure 3: Interrelationship between the RC and Key Parameters

Stakeholders Insights

- ***GBRAs Insights***

The GBRAs' insight showed that the number of generic residential GB projects far exceeded that of their GAH counterparts in the last five years. Their ratio was 1:8. Figure 4 [a] to [d] visualize the project locations against the state EE Index, the NSDP per capita, the climate zone, and the heatwave and flood vulnerability, respectively.



[a] State EE Index [b] NSDP per Capita [c] Climate Zone [d] Extreme Event Vulnerability

Figure 4: Correlations between Project Locations and [a] State EE Index, [b] NSDP per capita, [c] Climate Zone, and [d] Heatwave and Flood Vulnerability

Figure 4 [a] illustrates the superimposition of the project locations and the state EE index. The current study has been able to establish only an empirical relationship between the two, owing to the limited publicly available data concerning the projects. Also, the spread of GAH projects was found to be more aligned with the metric of NSDP per capita than the state EE Index, as visualized in Figure 4 [b]. In simplistic terms, this could mean that the wealthier states with higher NSDP per capita were better positioned to prioritize spending on GAH projects. Figure 4 [c] shows GAH projects to be scattered across all climate zones. Hence, no trend was found between project locations and climate zones. Figure 4 [d] illustrates the hazard vulnerability of the project locations. Here, the heatwave vulnerability was taken from [26]. It is represented as Heat Vulnerability Index (HVI) and highlighted in the form of the state's background colour, where red indicates a higher degree, and blue indicates the lowest degree of heatwave vulnerability respectively. Additionally, the flood vulnerability derived from [27] has been indicated as solid-blue-coloured circles. Figure 4 [d] indicates that the flood vulnerability has clear patterns across the coast and along the Ganga, Brahmaputra, and Sabarmati. Moreover, the central Indian states were seen to be the most vulnerable to heatwave hazards since the Tropic of Cancer passes over them. The states of Madhya Pradesh, Chhattisgarh, and Jharkhand were identified to be at the highest heatwave risk, yet they had the least penetration of GAH projects. Moreover, the states of Rajasthan, Uttar Pradesh, Maharashtra, and Odisha only had GAH projects in districts with lower heatwave vulnerability. Furthermore, the states of Uttar Pradesh and Bihar were seen to be vulnerable to both floods and heatwaves.

Figure 5 [a] illustrates the most commonly and rarely targeted Attributes per the GBRAs. The most commonly targeted Attributes were the ones related to the 'Site,' 'Energy,' 'Water,' and 'Material' Aspects. Contrarily, the most rarely targeted Attributes were the ones related to the 'Energy' and 'Practice' Aspects. Examining the Attributes' and Key Parameters' one-on-one relationship scores, it can be said that the most as well as least commonly targeted RC by GB projects can significantly strengthen Climate Response and Climate Resilience and directly contribute to affordability. Moreover, the groups of most and rarely targeted Attributes are not strongly linked with Gender Sensitivity.

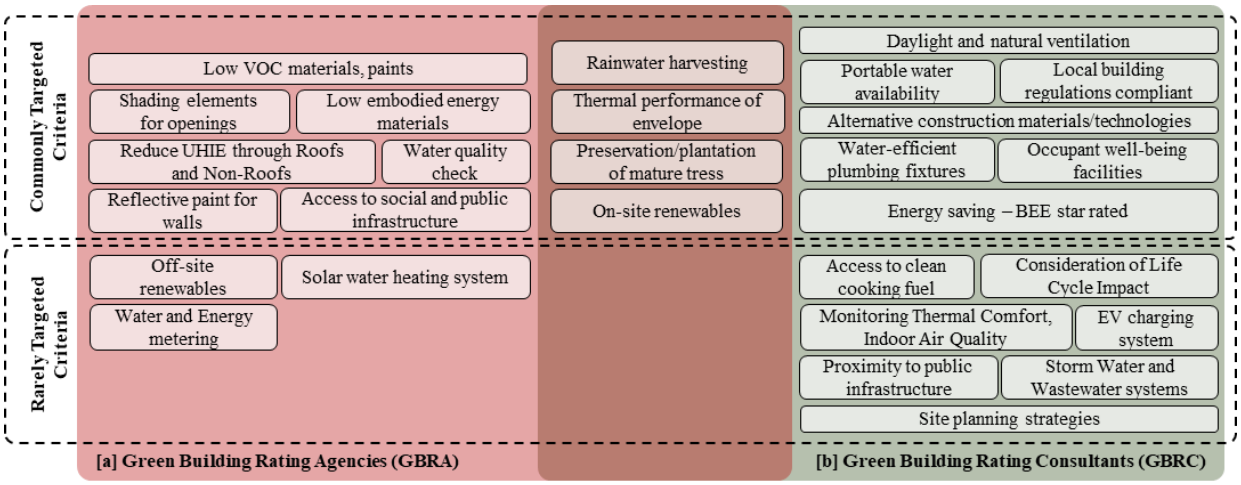


Figure 5: Most Commonly and Rarely targeted RC according to [a] GBRA and [b] GBRC

- ***GBRCs Insights***

Figure 5 [b] illustrates the most commonly and rarely targeted criteria per the GBRCs. The most commonly implemented Attributes are predominantly provision-based criteria; they have no spatial design-related implications on the project. The

GBRCs also highlighted that the Attributes of "Measures for Air Quality" and "Access to Clean Sources of Cooking Fuel" were rarely implemented in affordable housing projects. The 'Environment' related Attributes include "Provision of Proper Ventilation," "Provision of Daylight," and meeting requirements of "Adaptive Thermal Comfort." The GBRCs' responses indicate that an added money constraint would increase the difficulty and complexity of complying with those Attributes.

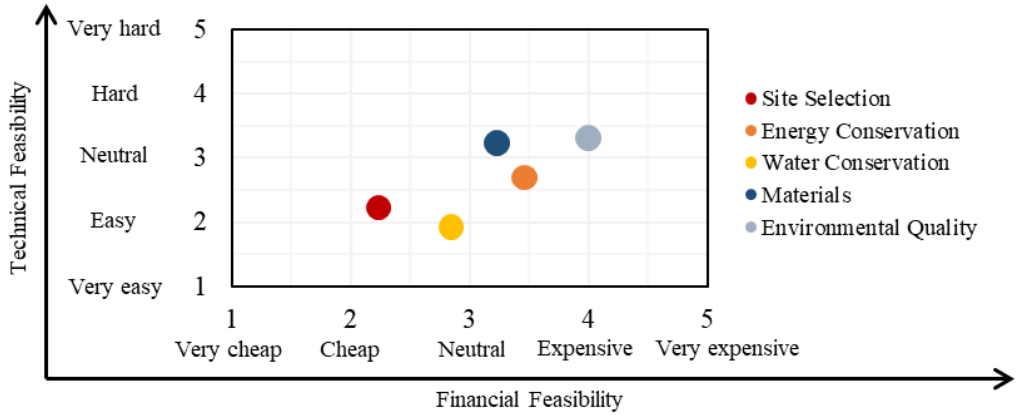


Figure 6: Technical and Financial Feasibility of Aspects

Figure 6 illustrates the average technical and financial feasibility score of various Aspects. The GBRCs' responses delineate that the 'Environment' Aspect is the most complex and expensive to implement in GAH projects. It can be seen that none of the Aspects made it to the ideal scenario, a combination of "Very Easy" in terms of technical feasibility and "Very Cheap" in terms of financial feasibility. The most viable Aspects were found to be "Water Conservation" and "Site Selection," as they fell within the "Neutral" boundary of both feasibilities.

Discussion

A list of Attributes directly (relationship score ≥1.5) influencing two or more Key Parameters was compiled and has been illustrated in Figure 7. These Attributes could impact all Key Parameters, improve occupant comfort and well-being, and render the envelope energy efficient. Moreover, compliance with Eco Niwas Samhita (ENS) [28] can achieve two Attributes. Thus, the prevailing GBRPs can benefit from including "ENS Compliance" as RC.

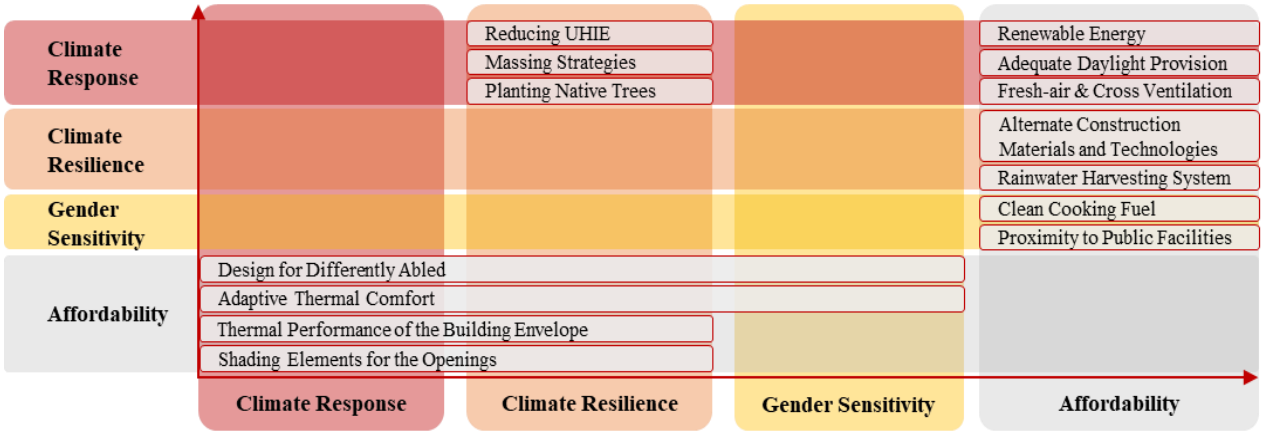


Figure 7: Attributes affecting more than one Key Parameter

The following elaborate on the gaps identified by this study:

a) ***GB's Intent Vs. Performance***: GBRPs certify buildings as '*Green'* based on their compliance with the RC – realizing the intent of the GB. However, there are little to no RC aimed at monitoring and ensuring that the certified GB also performs as a GB.

b) ***Clean Cooking Fuel Access***: It is the only Attribute that has the potential to impact operational carbon emissions and is related to Affordability as well as Gender Sensitivity. Nevertheless, this Attribute is not mandatory in any GBRP.

c) ***Incremental Cost and Split Incentive***: Incorporating green interventions in GB may be accompanied by additional upfront costs – often borne by the developer, which do not get passed onto the occupants; moreover, the occupants of GBs would pay lower operational costs. This creates a split incentive. Thus, the GBRPs can benefit from elaborating

on a) the maximum incremental cost and b) the mechanism to address and eliminate the split incentive between the occupants and developers.

d) ***Climate Resilience***: GBRPs have limited RC pertaining to heatwave and/or flood resilience. It must also be noted that both these disasters have seasonal occurrences. The GBRPs do not include any RC or credits involving seasonal strategies or preventive measures for extreme-event management. Moreover, since GBs are subject to disasters of varying intensity, it would make sense for the credits to be weighted accordingly with respect to the Site's disaster prevalence and intensity.

e) ***Adaptive Thermal Comfort***: Despite recent publications [29] suggesting that most heatwave casualties occur in the EWS and LIG, the "Adaptive Thermal Comfort" Attribute was not found to be mandatory in any of the GBRPs. Moreover, occupants' overall comfort is only addressed via post-occupancy surveys, including lighting levels, temperature, relative humidity, etc., while there are no established comfort requirements to adhere to. To ensure the GB's performance as '*Green*', the thermal comfort needs to be evaluated at the design stage through simulations. Moreover, the Residential Envelope Transmittance Value (RETV), as mentioned in the ENS 2017 [28], may serve as a preliminary indicator of thermal comfort. The RETV is a measure of heat escaping into the building, thus lowering the RETV and the occupants' discomfort. This criterion is potent enough to have a significant impact on the building's Climate Response, Climate Resilience, Gender Sensitivity, and Affordability.

f) ***Embodied Energy***: GBRPs include RC concerning the embodied energy of construction materials, but they are rather prescriptive. The percentage reduction in embodied energy with respect to a conventional 'Not Green' is not mentioned, let alone necessitated.

g) ***Supplementing urban-level systems***: Urban-level systems refer to the pre-existing municipal services, systems, and/or programs already in place for the zone/region where the GAH project would be developed. Hence, the GBRPs may benefit from incorporating RC that can supplement and downscale the Urban-level systems in place for waste, water, electricity, environment, and disaster management.

These gaps are essential from the point of view of GB's holistic sustainability. The GBRPs must integrate these gaps by adding new RC or enhancing the existing ones. However, this may not be limited to simply adding or enhancing RC. The prevailing GBRPs are intent-based; they will be required to shift their core ideology in order to create holistically sustainable GB.

Conclusion

This study assessed prevailing GBRPs in India from the perspective of Climate Response, Climate Resilience, Gender Sensitivity, and Affordability. It was found that the prevailing GBRPs approximately assimilate the RC pertaining to the four Key Parameters. However, they forgo the opportunity to establish and enhance the criteria for Climate Resilience. The inputs from GBRAs indicate that GAH projects are spread across the country. The most targeted RC were provision-based, while the least commonly targeted ones were related to spatial planning or building operation.

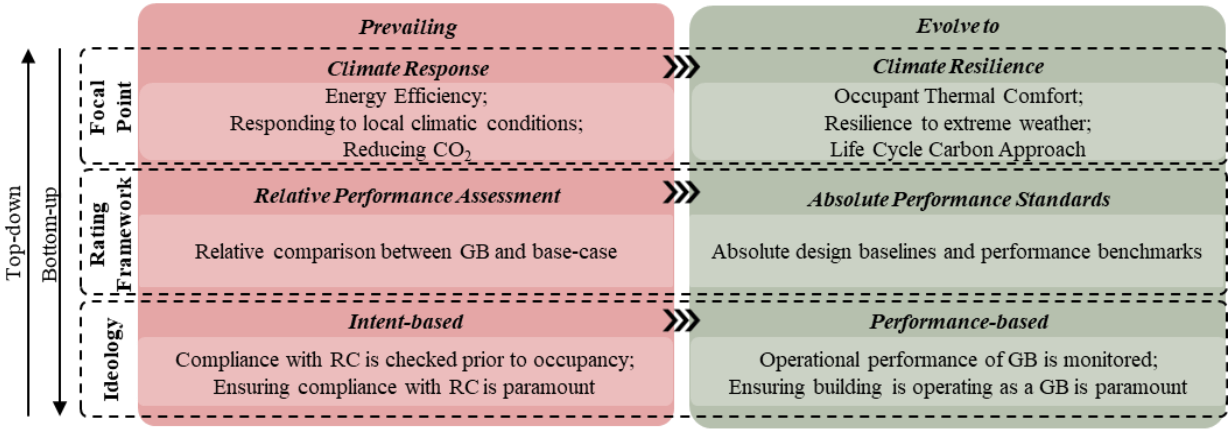


Figure 8: Guidance for enhancing prevailing GBRP

Prevailing GBRPs are primarily focused on mitigating climate change, i.e., Climate Response; their rating framework is relative-comparison based; and their core ideology is based on satisfaction of the intent of a GB. Figure 8 describes the domains in which the prevailing GBRPs may be required to evolve. The two methods – 'Bottom-up' and 'Top-down' are suggestive of the level of making change. The 'Bottom-up' approach would involve starting with surface-level changes, i.e., shifting the focus from Climate Response to Resilience. The 'Top-down' approach would involve making a change in the GBRP's core ideology, i.e., embracing a Performance-based appreciation.

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