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CASE STUDY

Green Rating for Integrated Habitat Assessment—A green-building rating system for catalysing climate-change mitigation/adaptation in India [version 1; peer review: 1 approved with reservations, 1 not approved]

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V1 First published: 07 Feb 2022, 11:153
<https://doi.org/10.12688/f1000research.108826.1>
 Latest published: 07 Feb 2022, 11:153
<https://doi.org/10.12688/f1000research.108826.1>

Abstract

Green-building rating systems (GBRSs) are critical for implementing climate change (CC) mitigation strategies because they can help reduce greenhouse gas (GHG) emissions from the building sector. From the Indian policy perspective, the ClimateSMART Cities Assessment Framework (CSCAF) provides cities a roadmap toward mitigating CC while planning/implementing their actions and facilitates realising energy efficiency and green buildings through GBRS adoption and incentivisation. Green Rating for Integrated Habitat Assessment (GRIHA) is a comprehensive GBRS aligned with CSCAF and India's climate goals, facilitating the implementation of Government of India's relevant policies and climate-adaptation measures within a building project's different phases. This paper examines existing institutional mechanisms for incentivising GRIHA-rated projects and provides recommendations for municipal bodies, regional developmental authorities, and state governments for strengthening resource efficiency in the built environment through GRIHA. Residential buildings are considered because their contribution to GHG emissions is the greatest among buildings. Data were collected through literature review, reviewing smart-city proposals and latest state annual action plans, Right to Information queries, and structured interviews of stakeholders. Feedback from green-building certification agencies, project proponents, and government officials revealed a need for local-level information dissemination and guidance on institutional mechanisms for incentivising green-rated projects. Further, to understand the implementation mechanisms for GRIHA-linked incentives, residential projects under some local-government agencies were documented as

Open Peer Review

Approval Status ? X

	1	2
version 1	?	X
07 Feb 2022	view	view
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case studies, providing useful insights into prevalent mechanisms for availing incentives while facilitating GRIHA compliance. The information provided herein can be useful for local governments in other developing countries for guiding the building sector toward mitigating climate change.

Keywords

Green-building rating systems, green-building policies, green-building incentives, climate change mitigation/adaptation, Green Rating for Integrated Habitat Assessment (GRIHA), SDG11 Sustainable Cities and Communities, SDG6 Clean Water and Sanitation, UN Sustainable Development Goals, SDG13 Climate Action, SDG17 Partnerships to achieve the Goal

This article is included in the **Energy** gateway.

This article is included in the **Climate** gateway.

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Author roles: **Kochhar P:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Mahal N:** Data Curation, Formal Analysis, Investigation, Writing – Review & Editing; **Seth S:** Resources, Supervision, Writing – Review & Editing; **Singh M:** Resources, Supervision, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

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How to cite this article: Kochhar P, Mahal N, Seth S and Singh M. **Green Rating for Integrated Habitat Assessment—A green-building rating system for catalysing climate-change mitigation/adaptation in India [version 1; peer review: 1 approved with reservations, 1 not approved]** F1000Research 2022, 11:153 <https://doi.org/10.12688/f1000research.108826.1>

First published: 07 Feb 2022, 11:153 <https://doi.org/10.12688/f1000research.108826.1>

1. Introduction

Buildings contribute to 39% of all energy-related CO₂ emissions (UN Environment and the International Energy Agency, 2017), of which, operational emissions (emissions from energy used for heating, cooling, and lighting buildings) account for 28% and the remaining 11% is from embodied carbon emissions associated with materials and construction processes throughout the entire building lifecycle (World Green Building Council, 2019). With the world's population projected to be mostly urban by 2050 (United Nations, 2018), this contribution will rise with rapid economic growth, particularly in developing countries. Therefore, for increasing stakeholders' awareness, publishing information regarding institutional mechanisms for implementing green-building rating system (GBRS)-linked incentives in the built environment is critical for expediting informed decision making.

According to the World Resources Institute (WRI) (WRI, 2020), the top 10 emitting countries (Figure 1) account for more than two-thirds of annual global GHG emissions: China leads with 26.1%, followed by the United States (12.67%), the European Union (7.52%), and India (7.08%). Moreover, residential buildings are the top contributors among buildings (Figure 2) (WRI, 2020).

GBRSs are the ideal tool for validating buildings' sustainability claims by setting performance benchmarks to promote improved construction and operational resource efficiency (Ramkumar, 2020). Although various GBRSs exist globally, tailoring them to suit local ecosystems, regulations, and requirements in developing countries (e.g., India) is important. Green Rating for Integrated Habitat Assessment (GRIHA) was India's first indigenous GBRS endorsed by the Government of India (GOI) and showcased at the United Nations Framework Convention on Climate Change (UNFCCC) as part of various initiatives for meeting India's climate goals (UNFCCC, 2015; Ministry of New and Renewable Energy (MNRE), GOI, 2019). Although GRIHA is over a decade old, further dissemination of information regarding its ground implementation

Figure 1. Top global greenhouse gas (GHG) emitters with sector-wise distribution of emissions.

World Greenhouse Gas Emissions in 2018

Total: 48.9 GtCO₂e

Figure 2. Sector-wise GHG emissions in 2018.

in different regions of India is required. In particular, guidelines are required for states, municipalities, and development authorities for formulating, endorsing, and enforcing green initiatives and policies to support India's CC commitments.

The ClimateSMART Cities Assessment Framework (CSCAF) is aimed to guide cities toward climate actions and help make them more responsive and less vulnerable to CC. CSCAF's "Energy and Green Buildings" category includes six important indicators, including "Promotion of green buildings" and "Green Building Adoption" (National Institute of Urban Affairs, 2019), which play an important role in CC mitigation and adaptation. Because domestic and commercial sectors consume approximately 33% of electricity (Ministry of Statistics and Programme Implementation, GOI, 2019; Bureau of Energy Efficiency (BEE), GOI, 2020) in India, significant untapped potential exists for realising highly energy-efficient and resilient buildings through the implementation of green-building policies and programs. Multiple documents (Climate Centre for Cities, 2020) provide information and examples from cities, international cases, and other organisations; however, only one relevant report—prepared by WRI India to address the requirements of the above-mentioned indicators (WRI India, 2020)—serves as a guidebook for local governments for green-building policy design and implementation. The report provides guidance on developing and implementing two specific types of building efficiency actions: green-building codes and certification/rating systems. Along with documenting the implementation of Energy Conservation Building Code (ECBC) in Hyderabad, the report provides information on implementing Pune Municipal Corporation's Eco-Housing Program, which is neither active nor a part of CSCAF. However, it lacks suggestions on implementing GBRs suggested in CSCAF (namely, Leadership in Energy and Environmental Design (LEED), Excellence in Design for Greater Efficiencies (EDGE), Green Rating for Integrated Habitat Assessment (GRIHA), Indian Green Building Council (IGBC) GBRs, and Green and Eco-friendly Movement (GEM)) or provide information on current institutional mechanisms that may be replicated/adopted or adapted by other cities. To address the mentioned gap, this paper examines existing institutional mechanisms for incentivising GRIHA-rated projects and provides recommendations for municipal bodies, regional developmental authorities, and state governments to improve CSCAF rankings by strengthening resource efficiency in the built environment through GRIHA to facilitate the implementation of various policies and schemes of GOI according to its international green commitments.

Further, case studies were conducted at the municipal and development-authority levels to study GRIHA's implementation according to the institutional mechanisms in place for availing incentives to provide improvement recommendations. This study aims to provide a comprehensive knowledge base, data, and guidelines for formulating and implementing policies, recommendations, and initiatives for boosting India's green-building efforts in the built environment, which constitute a vital part of the global efforts toward CC mitigation and adaptation. Moreover, this paper can provide a reference for local governments in other developing countries and help them in creating frameworks for CC mitigation and adaptation by guiding the building sector toward green-building practices.

2. Methods

The methodology adopted to accomplish the objectives of this study included literature review, exhaustive official-documentation review, stakeholder identification, designing of research tools such as structured interviews of the stakeholders identified, data collection and analysis, and formulating guidelines for effectively implementing green-building schemes.

2.1 Data collection and analysis

Literature and official documentation reviews for an in-depth understanding of linkages among CC, India's building sector, and India's Intended National Determined Contributions (INDCs) were conducted. To understand the city-level GBRS penetration level in the policy framework, smart-city proposals of all 100 cities under the Smart Cities Mission (SCM) (described in Section 4) and state annual action plans (SAAPs) prepared under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) for all 36 Indian states and union territories (UTs) were reviewed (see [Extended data](#)) ([Kochhar, 2022](#)). Furthermore, GRIHA and IGBC websites were studied to map information on GBRS-linked initiatives (including incentives, disincentives, and mandates) offered by various Indian states and UTs. Information on government-linked incentives for LEED, EDGE, and GEM is not publicly available on their websites and hence could not be included herein. The 100 Smart City proposals were reviewed to evaluate whether cities included GBRSs as a tool to achieve essential features of SCM guidelines (i.e., at least 80% buildings under redevelopment and green field should be energy efficient and green buildings) in area development plans ([Smart Cities Mission Statement and Guidelines, May 2015](#)). The latest SAAPs (see [Extended data](#)) ([Kochhar, 2022](#)) were reviewed to evaluate whether the proposed/completed reforms for conducting energy and water audits included green building incentives (e.g., rebate in property tax or charges connected to building permission/development charges) (Ministry of Housing and Urban Affairs (MoHUA), GOI, 2015). Information on green-building incentives, which is available online ([GRIHA, 2020](#); [Indian Green Building Council, 2015](#); [Administrative staff College of India and Natural Resources Defense Council, 2014](#)) and through notifications, was analysed in detail. A Right-to-Information (RTI) query was filed with the Town and Country Planning Department, GOI, to collect information on states that have integrated GBRSs in their building byelaws ([RTI query, 2020](#)). Structured interviews were conducted to identify challenges being faced by stakeholders that are awarding and availing incentives in states and municipal corporations with the highest number of policies and registered/green-rated projects. Several stakeholders, including municipal officials, private developers, project consultants, and residents of GRIHA-rated projects in New Okhla Industrial Development Authority (Noida) and Pimpri Chinchwad, were interviewed for case-study documentation.

Because GRIHA has established itself as the national rating for green buildings and drives policy compliance in India, states with a prominent GRIHA footprint, including Uttar Pradesh (UP) (7% of GRIHA project) and Maharashtra (40% of GRIHA projects), were shortlisted to identify case studies on the institutional mechanisms in place.

3. Role of various rating systems in mitigating climate change in India and abroad

GBRSs provide a framework for designing, implementing, and monitoring energy efficiency and CC mitigation and adaptation measures. Some green-design benefits to a building owner, user, and the society overall are as follows:

- Reduced energy consumption without sacrificing comfort levels
- Reduced destruction of natural areas, habitats, and biodiversity, and reduced soil loss from erosion
- Reduced air and water pollution (with direct health benefits)
- Reduced water consumption
- Limited waste generation due to recycling and reuse
- Reduced pollution loads
- Increased user productivity
- Enhanced image and marketability

Robust implementation of existing green-building policies and formulation of new interventions in the building sector at the national, state, and municipal levels ([Colenbrander et al., 2016](#)), including by providing incentives for GBRSs,

continue to be crucial in achieving India's INDCs. INDCs represent the principal mode for governments to internationally communicate their intended steps to deal with CC in their countries (WRI, 2021). In anticipation of the historic Paris Agreement in 2015 (UNFCCC, 2021), countries publicly outlined their intended post-2020 climate actions under the new international agreement, which were called their INDCs (WRI, 2021). GRIHA has been acknowledged in India's INDCs (UNFCCC, 2015).

3.1 GRIHA

In the Indian and global contexts, several GBRs exist (e.g., IGBC GBRs, GEM, CASBEE, BCA Green Mark, BREEAM, LEED, and EDGE). Globally, voluntary building-rating systems have been vital in increasing awareness and promoting green design. However, most of them were tailored according to the building industry of their origin country.

India's dynamic population and economic growth have resulted in a tremendous demand and construction of buildings, thereby exerting enormous pressure on resource availability. To achieve sustainability, policy makers are addressing the environmental pressures of increased resource demand coupled with a rapidly changing climate at different levels. Various policies and regulatory mechanisms have been devised and implemented through national plans and programs to address urban challenges. GOI ministries and agencies have designed frameworks, codes, and standards such as National Building Code (NBC) (SP 7: 2016 National Building Code of India 2016 (NBC 2016), December 14, 2018) for regulating building construction activities across India; Environmental Clearance (Ministry of Environment, Forests, and Climate Change (MoEFCC), 2014) to ensure resource-use efficiency for large projects (>20,000-m² built-up area); ECBC (A Report on Impact of Energy Efficiency Measures For the Year 2018–19, March 2020), which is applicable to air-conditioned commercial buildings with a connected load of >100 kW; the Solar Buildings Programme for Energy-Efficient Buildings (MNRE, GOI, 2019) for implementing renewable energy in buildings; AMRUT (Thrust Areas, October 25, 2021) for ensuring sufficient robust sewage networks and water supply; and SCM (About Smart Cities Mission, 2021) for promoting sustainable and inclusive cities. However, the greatest challenge arguably is building capacity and skills among stakeholders to devise solutions, effective ground implementation of such initiatives at the local level, and optimising their effectiveness. This could be achieved by encouraging a more holistic approach to building. Examples of some difficulties faced during the implementation of sustainable-habitat policies are the lack of disincentives for noncompliance, agencies and systems working in factions (i.e., different departments at the central and state governments independently examining areas such as energy efficiency, renewable energy, water resources, and waste management, contrary to a holistic approach that would address the building sector encompassing water, energy, etc. all together), and executing policies based on codes and standards before on-site verification, leading to on-site implementation challenges. Considering such challenges, and with the overall objective of reducing resource consumption and GHG emissions as well as enhancing renewable and recycled resource use by the building sector, The Energy and Resources Institute (TERI) developed GRIHA in 2005, which was adopted by the Ministry of New and Renewable Energy (MNRE), GOI, in 2007 (MNRE, GOI, 2019; MNRE, GOI, 2017; MNRE, GOI, 2020). GRIHA was also developed to indigenise design and implementation of resource efficiency for buildings in India because most international GBRs did not cater to the Indian real-estate sector's requirements in the 2000s. The GRIHA rating framework is an evaluation tool for measuring and rating a building's environmental performance, facilitating design, and evaluating a project throughout its lifecycle, including pre-construction, building planning and construction, and operation and maintenance stages. In addition to reducing the GHG emission from buildings, GRIHA optimises electricity consumption while meeting comfort requirements and reduces dependence on fossil fuel-based electricity and stress on natural resources. Other benefits of GRIHA-rated buildings include reduced air and water pollution, optimised water consumption, and waste management. GRIHA is based on a star rating system with a certain number of points required to achieve a particular star rating. A project must achieve minimum 50 points to qualify for GRIHA rating. A project's scoring to achieve GRIHA rating is as follows (Kochhar and Singh, 2021):

- 50–60 points: GRIHA 1-Star rated
- 61–70 points: GRIHA 2-Star rated
- 71–80 points: GRIHA 3-Star rated
- 81–90 points: GRIHA 4-Star rated
- 91–100 points: GRIHA 5-Star rated

Figure 3. Evolution of GRIHA (About Us, 2021).

As a tool, GRIHA includes qualitative and quantitative assessment criteria, which facilitate rating a building based on its level of “greenness”. GRIHA endeavours to minimise a building’s resource consumption, waste generation, and overall ecological impact to within specific nationally acceptable limits/benchmarks. **Figure 3** shows GRIHA’s evolution.

3.1.1 Why GRIHA?

GRIHA was the first GBRS endorsed by GOI. At the national level, MNRE incentivised GRIHA in 2007 and provided subsidies to projects by covering registration and certification fees (Ministry of Non-conventional Energy Sources (Urban, Industrial, and Commercial Group), GOI Notification, 2009), while internationally, MoEFCC presented GRIHA as the national rating system as part of India’s INDCs to UNFCCC for the Paris Convention. GRIHA was the India’s first GBRS to be adopted and adapted by the Central Public Works Department (CPWD) (*CPWD Office Memorandum, 2009*), an agency under MoHUA; CPWD’s green-building schedules and specifications were also formulated according to GRIHA (*TERI, 2012*). Further, GRIHA aligns itself with Indian codes and standards and, in 2006–07, was uniquely equipped to share feedback with BEE for ECBC compliance and with MNRE for renewable-energy installation. Over time, other rating systems have also emphasised on local-code compliance and been endorsed by various government agencies.

On a broader scale, GRIHA, in conjunction with associated activities and processes, will benefit the community overall with an improvement in the environment by reducing GHG emissions, energy consumption, and the stress on natural resources.

3.1.2 GRIHA as an implementation tool for climate-change mitigation policies

GRIHA attempts to quantify aspects such as energy consumption, waste generation, and renewable energy adoption to manage, control, and optimise them.

As an example (Construction World Staff, March 1, 2014), 10 million m² of a GRIHA 5-star-certified project can save sufficient electricity to power around 100,000 urban homes, save enough water to meet the needs of 22,000 urban homes, afford 6-MW photovoltaic (PV) installation to enhance electricity supply, and provide monitored data to ensure and strengthen compliance (*Construction World Staff website, March 1, 2014*).

As per the Efficient (EFF) scenario modelled by TERI (*TERI, 2018*), efficient space conditioning, urban and rural lighting, and refrigeration in the residential sector can potentially reduce energy intensity by up to 10% by 2031 (**Figure 4a**). By using the same EFF scenario, higher penetration of GRIHA-rated buildings in the commercial sector can potentially achieve up to 15% energy-intensity reduction by 2031 (**Figure 4b**).

Figure 4. Reference (REF) and Efficient (EEF) scenarios for reduction in energy intensity by (a) residential and (b) commercial buildings (Energy Efficiency Potential in India, 2018).

Besides being a tool that addresses CC mitigation through the evaluation of environmental performance of a building throughout its lifecycle, GRIHA addresses and alleviates risks caused by extreme heat, water scarcity, and flooding. GRIHA criteria embed CC-adaptation measures through the design, construction, and operational phases of building projects (GRIHA Council, 2020). Almost 50% of the points awarded in the GRIHA system have the potential to contribute toward CC adaptation and resilience as described below:

Measures for adaptation to extreme heat

- Low-impact design: Natural ventilation/low-energy cooling systems.
- Design to mitigate urban heat island intensity: Surfaces are soft paved/covered with high-solar-reflective coating, shaded by trees, pergolas, and/or solar panels.
- Preservation and protection of landscape (native/naturalised tree planting) during construction.
- Energy efficiency: Minimise overall heat gain and reduce energy demand for cooling.

Measures for adaptation to flooding

- Storm water management: 100% post-construction stormwater runoff management on site and scheme to deliver harvested rainwater to users.

Measures for adaptation to water scarcity

- Efficient water use during construction: Use of treated wastewater/captured rainwater in construction activities; strategies to reduce water use.
- Optimisation of building and landscape water demand: Installation of water-efficient systems such as low-flush toilets, use of regionally appropriate xerophyte plant species, and efficient landscape irrigation systems.

- Water reuse: Tertiary-level wastewater treatment for 100% of sewage generated on site, artificial groundwater recharge and rainwater storage, and maximum utilisation of treated and harvested water within the site to reduce the complete dependence on fresh water supply.

Measures to enable behaviour change by increasing awareness levels

- Create environmental awareness among building occupants and invitees.

Other measures

- Site plan must conform to the development master plan; provisions of ecosensitive, coastal, and heritage zones away from water bodies; and meeting “various hazard-prone area regulations”
- Strategies independent of other criteria that make the project more sustainable
- Quality of water available for use during the operational phase of the building meets national standards.

Graham and Rawal (2019) stated that GBRs in India are not yet key to achieving the emission reduction potential in India; however, they recommended that achieving the potential through effective implementation would be important toward the national effort.

3.1.3 ClimateSMART Cities Assessment Framework

To mitigate CC impacts, MoHUA launched the Climate Smart Cities Assessment Framework (CSCAF) in 2019 for 100 Smart Cities (MoHUA Press Release, 2020). CSCAF, which is a culmination of the major CC mitigation and adaptation schemes of GOI, facilitates the realisation of energy efficiency and green buildings through GBRs adoption and incentivisation. CSCAF's objective is to provide cities a clear roadmap toward mitigating CC while planning and implementing their actions, including investments (MoHUA Press Release, 2020). CSCAF has 28 indicators across five categories (Figure 5) to assist cities in understanding CC-linked challenges and improvement areas. Because GBRs facilitate energy efficiency implementation (among other benefits), the CSCAF for 100 smart cities (MoHUA, GOI, 2019) facilitates the inclusion of GBRs, including star labelling for buildings by GRIHA, EDGE, LEED, IGBC, and GEM. CSCAF also serves as a culmination of other schemes such as Green India Mission, National Clean Air Programme, AMRUT, and Swachh Bharat Mission in achieving the objective of being “Climate Smart.”

In the first phase of city assessment according to CSCAF, 96 cities including more than 27 government departments/organisations from a three-tier governance structure—national, state, and city—along with other stakeholders participated and provided inputs for >120 datasets. Cities submitted data on the official portal; an Expert Committee evaluated these submissions. With an intent to inform cities on their climate readiness, the first baseline assessment for each city was announced.

Information from knowledge-sharing platforms revealed that cities were learning from each other's experiences and were motivated to work toward tackling CC impacts collectively. The success stories, best practices, advisories, and other reference material from the first assessment are available on SmartNet (ClimateSmart Cities, 2019) to help other cities in their endeavour.

4. Key climate-change initiatives by Indian government agencies for climate-change mitigation and adaptation through the built environment

Different GOI ministries, such as the Ministry of Power (including Energy Efficiency Services Limited and BEE); MNRE; Ministry of Housing and Urban Poverty Alleviation (including CPWD; Bureau of Indian Standards); and MoEFCC, have played a key role in designing policies and incentives for projects to incorporate resource efficiency through GBRs, in turn meeting India's INDCs (Figure 6).

With an objective to drive economic growth and improve people's quality of life by enabling local-area development and harnessing technology, especially technology that leads to “smart” outcomes, GOI launched SCM in 2015 (About Smart Cities Mission, 2021). In the Indian context, the smart-cities concept is based on six fundamental principles: (i) communities at the core of planning and implementation; (ii) ability to generate greater outcomes using lesser

Figure 5. Climate Smart Cities Assessment Framework categories and indicators (ClimateSmart Cities Assessment Framework 2.0 – Chapter 4: Indicator Description, 2021).

Figure 6. Green-building policy framework instituted by the Government of India.

resources; (iii) cities selected through competitions with flexibility to implement projects; (iv) innovating methods for integrated and sustainable solutions; (v) careful selection of technology, relevant to the cities' context; and (vi) sectoral and financial convergence (About Smart Cities Mission, 2021). SCM envisions developing areas within 100 cities in India as model areas based on an area-development plan. Each city has a mandate to create a special-purpose vehicle, presided by a full-time chief executive officer, to implement SCM. Cities are selected in two stages: (1) 100 smart cities are distributed among the states and UTs based on unbiased criteria and (2) each potential city prepares its Smart City Proposals, which contain the model chosen (retrofitting or redevelopment or greenfield development or a mix thereof) in addition to a pan-city dimension (100 Smart Cities Mission, 2021). According to information available on the MoHUA website (About Smart Cities Mission, 2021) Rs. 2,005,018-million investment is proposed across 100 cities and projects worth Rs. 531,760 million have been completed (About Smart Cities Mission, 2021). Along with SCM, AMRUT (The Mission, 2015) was launched in 2015 focusing on establishing infrastructure for ensuring sufficient robust sewage networks and water supply for urban transformation by implementing urban revival projects. In 2015, the Union Ministry of Urban Development announced the Smart Cities Challenge (SCC) (100 Smart Cities Mission, 2021), which aims to create exemplar areas in cities by merging innovative plans with latest technologies. By creating these replicable exemplar areas, SCC aims to redefine the way a city is imagined in India. SCC intends to find solutions to major problems in cities by merging innovative plans and latest information technologies, improve economic opportunity and quality of life, and ensure public accountability. As per the city challenge reports submitted (City Challenge, 2021), only 25 out of 100 cities have included green-building certification as a means to achieve select essential features, requiring "At least 80% buildings (in redevelopment and green field) ought to be energy efficient and green buildings" (*Smart Cities Mission Statement and Guidelines, 2015*). Twenty-two SAAPs submitted as a part of AMRUT (SAAP 2017–2020, 2020) attempt to "award incentives for green buildings (e.g., rebate in property tax or charges connected to building permission/development charges)" (*SAAP - Atal Mission for Rejuvenation and Urban Transformation, 2015*). Furthermore, Andaman and Nicobar Islands, Andhra Pradesh, Chhattisgarh, Himachal Pradesh, Jharkhand, and UP have issued directions to incentivise green-rated buildings, as reported in their respective SAAPs (SAAP 2017–2020, 2020).

The use of GBRs as implementation tools for AMRUT and SCM facilitates a bottom-up approach, thereby enabling improved transparency and efficiency between state governments and municipal bodies. Fifteen states and UTs—Andhra Pradesh, Chandigarh, Chhattisgarh, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Manipur, Delhi, Punjab, Telangana, UP, Uttaranchal, and West Bengal—have endorsed GBRs as part of their revised or updated building byelaws (*RTI query, 2020*). *Smith and Pathak (2018)* have identified GBRs as effective tools to achieve urban transformation at the level of urban local bodies by implementing relevant components of SCM (*Smart Cities Mission Statement and Guidelines, 2015*) and AMRUT.

Feedback from certification agencies, project proponents, and government officials has indicated that comprehensive information dissemination on institutional mechanisms is needed for municipal bodies to integrate GBRs within their existing framework.

In India, green buildings are generally perceived as more cost intensive than regular buildings, which is a major barrier in their extensive adoption. This challenge is particularly pronounced in residential buildings, where private developers bear the incremental costs and occupants reap the recurring benefits of low operating costs. *Table 1 (MoHUA, GOI, 2019)* presents percentage savings in resource consumption achieved by green-rated buildings versus conventional buildings and indicative increase in cost of green-rated buildings, which may (in part) be set off by incentives.

At the state and municipal levels (*Table 2*), 17 States and UTs (out of 36 States and UTs (*States and Union Territories, 2021*)) have incentivised (by providing financial incentives, additional ground coverage, additional floor area ratio (FAR)/ floor space index (FSI)/building area ratio (BAR)) or issued direction for mandatory compliance with various GBRs to achieve goals set at the national level, which facilitate and contribute to achieving INDCs.

GBRs in India provide implementation mechanisms for national- (*Figure 4*), state-, and local-level policies (*Table 2*) to achieve resource efficiency in the built environment (Knowledge Repository, 2021; Lok Sabha Questions, December 13, 2018; *Kochhar, 2010*). They also facilitate building performance monitoring and quantification (*Graham and Rawal, 2019*), which supports capture, management, and public availability of data toward reporting of India's INDCs. GBRs are embedded in local-level policies, while agencies mandate GBRs through integration in building byelaws and provide GC and FAR incentives. GBRs (in general) and GRIHA for new and existing buildings (in particular) incorporate ECBC and the Standards and Labelling program for appliances (issued by BEE, Ministry of Power), which are closely aligned with the environmental-clearance norms for buildings issued by MoEFCC and mandate renewable-energy integration (aligned with MNRE objectives) (*Ministry of Environment and Forests (MoEF), GOI Office Memorandum, 2011*). Furthermore, GBRs are also aligned with the National Action Plan on Climate Change, incorporate relevant sections of NBC, and

Table 1. Resource savings and incremental costs incurred by green-rated buildings (MoHUA, Government of India, 2019).

Certification type	Commercial					Residential					Cost increment (%)	Waste water reduction (%)	Solid waste reduction (%)	Water savings (%)	Energy savings (%)	Water savings (%)	Solid waste reduction (%)	Waste water reduction (%)	Cost increment (%)
	Energy savings (%)	Water savings (%)	Solid waste reduction (%)	Waste water reduction (%)	Cost increment (%)	Energy savings (%)	Water savings (%)	Solid waste reduction (%)	Waste water reduction (%)	Cost increment (%)									
Green case	10	40-46	46	28-43	0.7-2.5	35	36-41	46	52-67	0.7-2.2									
GRIHA 1 star	36	69-100	51	67-76	2.5-6.6	43	47-72	51	58-81	2.6-3.8									
GRIHA 3-star	54	69-100	55	72-86	6.5-11.9	57	57-83	55	66-88	4.8-5.2									
GRIHA 5-star	61	75-100	60	86-92	9.7-14.8	64	68-90	60	85-88	6.5-7.7									

Table 2. GBRS mechanisms for implementing climate-change mitigation/adaptation policies at the local level.

S. No	State/UT	Name of local/municipal body	Type of compliance mechanism
1	Andhra Pradesh	Municipal Administration and Urban Development Department	Financial incentives
2	Andhra Pradesh	Industries and Commerce Department	Financial incentives
3	Delhi	Delhi Development Authority	Ground coverage and FAR incentive
4	Chandigarh	Chandigarh Administration	Mandatory compliance
5	Goa	Department of Town and Country Planning (TCP)	Mandatory compliance
6	Gujarat	Urban Development and Urban Housing Department	Additional FAR/FSI incentive
7	Gujarat	Industry and Mines Department	Financial incentives
8	Gujarat	Ahmedabad Urban Development Authority	Additional FAR/FSI incentive
9	Haryana	Haryana Renewable Energy Development Agency	Mandatory compliance
10.	Haryana	Department of TCP	Additional FAR/FSI incentive
11.	Himachal Pradesh	Department of TCP	Additional FAR/FSI incentive
12.	Jharkhand	Urban Development and Housing Department	Additional FAR/FSI incentive
13.	Kerala	Public Works Department (PWD)	Mandatory compliance
14	Maharashtra	Urban Development Department (UDD)	Financial incentives
15	Maharashtra	UDD	Additional FAR/FSI incentive
16	Maharashtra	PWD	Mandatory compliance
17	Maharashtra	Pune Municipal Corporation	Financial incentives
18	Maharashtra	Pimpri Chinchwad Municipal Corporation	Financial incentives
19	Odisha	Bhuvneshwar Development Authority	Incentive as per State policy
20	Punjab	Department of Local Government (DLG)	Mandatory compliance
21	Punjab	DLG	Additional FAR/FSI incentive
22	Punjab	PWD	Mandatory compliance
23	Punjab	Department of Housing and Urban Development	Additional FAR/FSI incentive
24	Rajasthan	UDD	Additional FAR/FSI incentive
25	Rajasthan	Department of Urban Development and Housing, Department of Local Self Government	Additional FAR/FSI incentive
26	Rajasthan	Jaipur Development Authority	Additional FAR/FSI incentive
27	Sikkim	Building and Housing Department	Mandatory compliance
28	Uttar Pradesh (UP)	Greater Noida Industrial Development Authority	Additional FAR/FSI incentive
29	UP	Housing and Urban Planning Department (HUPD)	Additional FAR/FSI incentive
30	UP	HUPD	Additional FAR/FSI incentive
31	UP	NOIDA and Greater NOIDA local bodies, UP	Additional FAR/FSI incentive
32	Uttarakhand	Mussoorie Dehradun Development Authority (MDDA)	Additional FAR/FSI incentive
33	Uttarakhand	MDDA	Mandatory compliance
34	West Bengal	Department of Urban Development and Municipal Affairs	Additional FAR/FSI incentive
35	West Bengal	New Kolkata Development Authority	Additional FAR/FSI incentive
36	West Bengal	Department of Municipal Affairs	Additional FAR/FSI incentive

Note: For details regarding the incentives, please refer to Incentive wise_Municipal level in extended data.

facilitate partial implementation of SCM and AMRUT, which are important initiatives of MoHUA. Considering the above-mentioned alignment with the objectives of GOI ministries, GBRs have been embedded in local-level policies to ascertain action toward CC mitigation and adaptation. Nine local bodies mandate GBRs through their integration with building byelaws, 21 provide ground coverage and/or FAR incentives, and six provide financial incentives. [Table 2](#) provides information on the local bodies that have employed GBRs to achieve CC mitigation and adaptation goals.

[Table 2](#) provides cities and municipalities a roadmap that can help to enhance their scores based on the CSCAF framework through implementation of green-building policies and incentives.

5. Methods of meeting GRIHA requirements according to CSCAF

5.1 Incentives and mandates at municipal and state levels

Green-rated project incentives provide an institutional framework at the state and municipal levels to implement policies, including the CSCAF developed for 100 Smart Cities, and enable cities to achieve the objective of being “Climate Smart.”

UP (nine policies), Gujarat (seven policies), Maharashtra and Punjab (six policies each), and Andhra Pradesh and West Bengal (five policies each) are states ([Table 3](#)) that utilise GBRs, particularly GRIHA, to implement CC mitigation, adaptation, and resilience policies ([GRIHA Council, 2020](#)).

Table 3. Green-rated projects driving policy implementation at state and municipal levels.

S. No.	State/UT	Incentives/mandate for green rating	Provision for green-building incentives in AMRUT SAAPs	Green rating in Smart City proposals	Endorsement of green rating in byelaws/other documents	Total
1	Andaman and Nicobar Islands	-	1	-	1	2
2	Andhra Pradesh	2	1	1	1	5
3	Arunachal Pradesh	-	1	1	1	3
4	Assam	-	1	-	-	1
5	Bihar	-	1	1	-	2
6	Chandigarh	1	1	-	1	3
7	Chhattisgarh		1	2	1	4
8	Dadra and Nagar Haveli and Daman and Diu	-	1	1	-	2
9	Delhi	1	1	-	1	3
10	Goa	1	-	-	-	1
11	Gujarat	3	1	2	1	7
12	Haryana	1	-	1	1	3
13	Himachal Pradesh	1	1	1	-	3
14	Jammu and Kashmir	-	1	1	-	2
15	Jharkhand	1	1	1		3
16	Karnataka	-	1	-	1	2
17	Kerala	1	1	-	1	3
18	Ladakh	-	-	-	-	
19	Lakshadweep	-	-	-	1	1
20	Madhya Pradesh	-	-	2	-	2

Table 3. *Continued*

S. No.	State/UT	Incentives/mandate for green rating	Provision for green-building incentives in AMRUT SAAPs	Green rating in Smart City proposals	Endorsement of green rating in byelaws/other documents	Total
21	Maharashtra	3	-	1	2	6
22	Manipur	-	-	-	1	1
23	Meghalaya	-	1	-	-	1
24	Mizoram	-	1	-	-	1
25	Nagaland	-	1	1	-	2
26	Odisha	-	1	-	-	1
27	Puducherry	-	-	-	-	-
28	Punjab	3	1	1	1	6
29	Rajasthan	3	-	1	-	4
30	Sikkim	1	1	-	-	2
31	Tamil Nadu	-	1	2	-	3
32	Telangana	-	1	-	1	2
33	Tripura	-	1	1	1	3
34	UP	4	1	3	1	9
35	Uttarakhand	2	-	1	1	4
36	West Bengal	3	1	-	1	5

Noida in UP with more than 100 green buildings (M. Goyal, personal communication, September 1, 2020), Pimpri Chinchwad Municipal Corporation (PCMC) with over 60 GRIHA projects (K. Karmarkar, personal communication, September 1, 2020), and the state of Haryana with over 30 green buildings (H. Singh, personal communication, September 1, 2020) are eligible to receive the green rating-linked additional FAR incentive.

Select GRIHA projects in the above-mentioned regions were identified for supporting information on implementation mechanisms. Developers, namely Goel Ganga Developers (A. Goel, personal communication, August 28, 2020) and Sanjeevani Developers in Pimpri Chinchwad (S. Deshpande, personal communication, August 29, 2020) and the DAH group in Noida, were interviewed (S. Sadarangani, personal communication, August 30, 2020) to gain information on the role of incentives in offsetting any additional costs incurred by the developers in the design and construction of green buildings. Occupants of the GRIHA-rated Ganga Skies project were interviewed (Mahal, 2016) to understand the impact of property tax rebates during residence in a green building.

5.2 Green building-linked financial incentives by municipal corporations

5.2.1 GRIHA-linked incentives by PCMC

In 2011, PCMC launched GRIHA-linked incentives under a scheme called “energy-efficient solar/green buildings” by MNRE (MNRE, GOI report, 2018). According to the incentive scheme (Table 4), and depending on the level of GRIHA rating, the project developer is eligible to avail 10%–50% discount in Premium¹ and occupants are eligible to avail property tax benefit (between 5% and 10%) based on the final rating (Green Building Initiative, 2021). Furthermore, according to the office memorandum released by the MoEF, GOI (MoEF, GOI Office Memorandum, 2011), a GRIHA pre-certified project would be eligible for “out-of-turn priority attention by the Expert Appraisal Committee (EAC)/State-Level Expert Appraisal Committee (SLEAC).”

5.2.2 Operationalisation of GRIHA-linked priority consideration by EAC/SLEAC

The following steps need to be followed to operationalise GRIHA-linked priority consideration for a project by EAC/SLEAC:

¹ Premium is a fee paid by developers to PCMC, similar to infrastructure tax paid in other municipal corporations.

Table 4. Discount in Premium and property tax rebate for GRIHA projects in PCMC (Green Building Initiative, 2021).

Points scored	Rating	Discount in premium		Discount in property tax
51–60	1-Star	10%	For the first 25 GRIHA projects	-
61–70	2-Star	20%		-
71–80	3-Star	30%		5%
81–90	4-Star	40%		8%
91–100	5-Star	50%		10%

- Register the project at www.grihaindia.org
- Submit a proposed development plan for the registered project with recent date-stamped site photographs
- GRIHA Council to review feasibility
- Successful payment of registration fee to access the GRIHA Online Panel
- Project team to upload compliance documents through the online panel
- Submitted documents evaluated by GRIHA Council
- GRIHA Council to revert with comments on the submitted documents within two weeks
- Revised documents to be submitted by the clients within two weeks of receiving comments
- Documents evaluated by a pre-certification committee
- In case of compliance, pre-certification is awarded along with a detailed compliance report
- In case of non-compliance, a report with necessary corrective actions is shared
- GRIHA registration of project is mandatory after pre-certification
- GRIHA rating to be pursued as per GRIHA Council procedure

5.2.3 Operationalisation of GRIHA-linked incentives at PCMC for project developers

The process to avail GRIHA incentives under PCMC (Green Building Initiative, 2021) is appended below:

- Register project at www.grihaindia.org
- Payment of registration fee and access to GRIHA Online Panel
- One-day GRIHA workshop for project team by GRIHA Council
- First due-diligence site visit conducted by GRIHA Council (when project construction is at plinth level) and report (with feedback) uploaded online for project team
- Compliance report submitted by project team within 15 days of the first site visit
- Second due-diligence site visit conducted by GRIHA Council upon completion of superstructure and second report uploaded online for the project team

- Compliance report submitted by project team within 15 days of the second site visit
- Project team to upload GRIHA documentation for all criteria
- Primary evaluation by GRIHA Council on completeness of the documentation
- Third and final due-diligence site visit conducted by GRIHA Council
- GRIHA evaluation committee reviews GRIHA documentation for award of provisional points
- Project evaluation report uploaded online. Project team may submit additional documents within 30 days of uploading evaluation report.
- GRIHA provisional rating and certificate issued by GRIHA Council
- Post-occupancy audit conducted by BEE-certified auditor
- Award of final GRIHA rating after building is fully commissioned and is operational for at least 12 months.
- Developer to submit GRIHA rating certificate to PCMC for release of rebate on Premium. Environment Cell of PCMC notifies tax department to issue applicable rebate in Premium.
- Tax department to release rebate on property tax for occupants of the property for three consecutive years, after which the building to be re-audited for energy, water, and waste (report to be prepared by BEE-certified energy auditor) every three years to avail the property tax benefit.

5.2.4 Impact of incentives on PCMC

Based on information from PCMC (K. Karmarkar, personal communication, September 1, 2020), around 60 projects registered till 2019 are eligible to avail incentives. It had been inferred ([Green Building Initiative, 2021](#)) that on an annual basis, if the PCMC revenue from Premium is Rs. 1 billion², then the revenue invested for 3-Star GRIHA projects through rebates would be approximately Rupees (Rs). 40 million. In turn, a 35% reduction in the quantity of potable water required, 35% reduction in the amount of wastewater generated, and 15% of treated wastewater to be used for various applications in new buildings are expected, thereby reducing the pressure of providing services and maintaining infrastructure.

In the case of property tax rebate for a typical case, where the end user pays an annual base tax of Rs. 6000/- for a 92.9-m² flat, a rebate of Rs. 600/- per annum would be available for a 3-Star GRIHA project ([Green Building Initiative, 2021](#)). Similarly, for a 4645.2-m² property (around 50 flats) and a 37,161.2-m² property (around 400 flats), a tax rebate of Rs.30,000/year and Rs. 240,000/year would be applicable, respectively. In turn, the project would benefit through rainwater harvesting, solid waste management, and availability of solar thermal systems on site.

5.3 Green-building rating-linked additional FAR incentive by a development authority

5.3.1 Green-building rating-linked incentives by Noida

In 2010, as part of the General Provisions for building projects, Noida included additional free FAR for LEED-certified projects constructed on plot sizes of >5000 m² (NOIDA and Greater NOIDA embrace GRIHA. GRIHA incentives, October 20, 2012; M. Goyal, personal communication, September 1, 2020). Subsequent amendments in 2012 and 2019 included incentives for GRIHA- and IGBC-certified projects as well.

5.3.2 Operationalisation of green building rating-linked incentives at Noida for project developers

The process to avail green building-linked incentives in Noida (NOIDA and Greater NOIDA embrace GRIHA. GRIHA incentives, October 20, 2012; M. Goyal, personal communication, September 1, 2020) is appended below:

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²74.28 Indian Rupee = 1 USD (as on January 8, 2022).

- Applicant submits LEED/GRIHA/IGBC pre-certification to the Town Planning Department of Noida to seek 5% additional free-of-cost FAR for green building.
- At the time of seeking a completion certificate, the applicant to provide final LEED/GRIHA/IGBC rating certificate to Noida.
- The applicant is required to submit a rating certificate and a certificate of compliance every five years. In case the client fails to do so, the authority—after one month's notice—may charge the compounding fees of the FAR given free of cost at a rate of 200% of the cost of purchasable FAR.

5.4 Green-building rating-linked additional FAR incentive by a state

5.4.1 Green-building rating-linked incentives by Haryana

With an objective to synchronise the provisions of building rules across the state, the Government of Haryana issued the Haryana Building Code in 2017 ([The Haryana Building Code 2017, 2021](#)), which incorporates the requirements of the Model Building Byelaws (Model Building Bye Laws, 2016).

The Haryana Building Code provides green-building measures and incentives (for new buildings) where projects certified as green buildings are eligible for additional FAR incentives ([Table 5](#)). Furthermore, “in case the building is certified from GRIHA, there is no requirement for issuing environmental clearance” (MoEF, GOI Office Memorandum, 2011). The applicant only has to pay the Infrastructure Development Charges on additional FAR granted as incentive under Code 6.5, i.e., green-building measures and incentives, and not the fee for availing extra FAR (H. Singh, personal communication, September 1, 2020).

5.4.2 Operationalisation of green building rating-linked incentives in Haryana

The process to avail green building rating incentives in Haryana ([The Haryana Building Code 2017, 2021](#); H. Singh, personal communication, September 1, 2020) is appended below:

1. Applicant is required to submit provisional certificate from GRIHA or precertification from IGBC/LEED at the time of seeking approval of building plan, to the Competent Authority.
2. Applicant is required to submit final rating certificate from GRIHA/IGBC/LEED at the time of applying for the Occupation Certificate of building.
3. Competent Authority verifies final level of rating achieved with the provisional/precertification rating and issues Occupation Certificate, and approves claim of additional FAR if final rating is same/higher than the provisional rating.
4. In case the final rating achieved is lesser than the provisional rating, occupation certificate is issued after compounding the additional FAR (i.e., difference of additional FAR from provisional rating and final rating) acquired by the applicant, at 10 times the rates of External Development Charges (EDC) ([The Haryana Building Code 2017, 2021](#)) applicable at the time of submission of occupation certificate application.
5. The applicant to submit a rating certificate for the building from GRIHA/IGBC/LEED every 5 years. In case of non-compliance, the authority, after giving one month's notice may charge compounding fee or may take appropriate action on a case-by-case basis.

Table 5. Details of green-building rating and additional FAR (H. Singh, personal communication, September 1, 2020).

Additional FAR for all building uses (except plotted residential)	3%	6%	9%	12%	15%
GRIHA rating	1-Star	2-Star	3-Star	4-Star	5-Star
IGBC/LEED rating	-	-	Silver	Gold	Platinum

6. Case studies

To evaluate GBRS implementation and its outcome in residential projects, case studies were conducted for some projects under two municipal corporations and one development authority. The following subsections are dedicated to these case studies.

6.1 Case study 1: 3-Star Ganga Skies residential project, Pimpri Chinchwad

The 3-Star GRIHA-rated residential project (Figure 7) (56,000-m² built-up area) availed 30% rebate in Premium. The occupants were entitled to a 5% property tax rebate. In addition, the project could achieve 8% reduction in capital cost by integrating green-building principles at appropriate design, planning, and implementation stages (Mahal, 2016).

The environmental benefits accrued by the project as part of GRIHA (Construction World Staff, March 1, 2014) are listed below:

- 30% reduction in energy consumption compared with the GRIHA benchmark.
- 25% reduction in building water consumption.
- 40% reduction in landscape water consumption.
- More than 50% of the living areas are day-lit.
- More than 40% fly-ash used in the block work.
- 10-kW renewable energy generated on site.

6.2 Case study 2: 3-Star Devrai Phase II residential project, Kiwale, Pune

The 3-Star GRIHA-rated residential project (Figure 8) of 3100-m² built-up area (Complete, GRIHA, Projects, Pune, Residential. Devrai, Phase II, September 2019) availed 30% rebate in Premium. The occupants were entitled to a 5% property tax rebate, resulting in annual savings (Incentive release approval for GRIHA rated project by PCMC, September 2019; GRIHA Council organised “Paryavaran Rakshak” programme for occupants of Devrai Phase-II, Pune, September 21, 2019).

The environmental benefits accrued by the project as part of GRIHA are listed below (Complete, GRIHA, Projects, Pune, Residential. Devrai, Phase II, September 2019):

Figure 7. Ganga Skies project, Pimpri Chinchwad, Maharashtra (CW Staff, March 1, 2014).

Figure 8. Devrai project, Kiwale, Maharashtra (Complete, GRIHA, Projects, Pune, Residential. Devrai, Phase II, September 2019).

- 85% estimated reduction in energy consumption compared with the GRIHA benchmark.
- 76% water savings in landscape usage due to drip irrigation installation.
- More than 90% of interior day-lit spaces.
- Solar hot-water system to meet 96% of hot water requirement, thus reducing the consumption of energy generated from non-renewable sources.
- 3-kWp solar photovoltaics installed for common-area lighting.
- 29% reduction in embodied energy in structural application.

6.3 Case study 3: GRIHA 4-Star NX-One project, Greater Noida

The GRIHA pre-certified mixed-use project of approximately 338,402.6-m² built-up area (Figure 9) (S. Sadarangani, personal communication, September 12, 2020) and cost of Rs. 8000 million (View Projects, September 14, 2020) availed 5% additional free-of-cost FAR of 11,745 m². The cost of additional free-of-cost FAR provided to the project (calculated according to the compounding fee letter of Noida (M. Goyal, personal communication, September 1, 2020)³, using rate of purchasing commercial/residential FAR) is approximately Rs. 768 million to the developer. The projected incremental cost (as the project is still under construction) incurred to meet the requirements of GRIHA 4 Star (including solar reflectance index tiles, fly-ash bricks, double glazing, roof insulation, BEE-rated ceiling fans, solar PV power plant, and HVAC automation) is approximately Rs. 694.5 million (S. Sadarangani, personal communication, September 12, 2020).

³ According to discussion with Noida Authority officials, the compounding fee for projects in Greater Noida is same as that for projects in Noida.

Figure 9. GRIHA 4-Star pre-certified NX-One, Greater Noida, Uttar Pradesh (Sharma and Tomar, 2010).

Thus, the additional cost incurred by the project is absorbed by the value of the free FAR incentive for GRIHA projects provided by Greater Noida.

6.3.1 Impact of incentives on NOIDA

Based on information from Noida (M. Goyal, personal communication, September 1, 2020), over 100 projects (i.e., almost 80% of total eligible projects (plot size of $>5000 \text{ m}^2$) that apply for building permission) have registered between 2010 and 2020 with LEED/GRIHA/IGBC to avail the additional free-of-cost FAR incentive awarded based on byelaw provisions by the authority. This initiative has encouraged private developers to adopt green-building practices, with negligible impact on Noida's revenues. Numerous group-housing projects have applied for the incentive, but because almost 90% of the projects are partly complete, the final sanction is awaited.

7. Discussion

States, particularly where SCM and AMRUT schemes are being actively implemented, are able to ensure resource efficiency through GBRs (Table 2), e.g., UP, Haryana, and Maharashtra (see Extended data) (Kochhar, 2022).

Green-building certification agencies are equipped to support local bodies for data capture, management, and public availability of data. Availability of updated and correct data on sustainability performance at a local level has traditionally been a challenge, which has been addressed in the case of PCMC to some extent. Building a robust system for demand-side resource-consumption data collection and analysis at local and state levels will contribute significantly toward collating information for India's INDCs.

The use of existing green-building rating tools enables effective implementation of resource-efficiency policies at the building and municipal levels, enables municipal bodies to measure and monitor progress, and provides a feedback mechanism for modifications required (if any) in the rating systems.

For project proponents and municipal bodies, understanding the cost impact of green-rated buildings over a project's lifecycle is crucial for designing appropriate incentive mechanisms. Further study on building performance and cost analysis of GRIHA-rated projects is required, which will also enable designing suitable incentives at state or municipal levels.

The recommendations for states and municipal bodies to institutionalise GRIHA and incentivise projects are as follows:

7.1 GBRS adoption

- Develop relevant schemes including GRIHA, which should clearly highlight priorities and intentions by ensuring that GRIHA is embedded in an existing framework or issued via an official government order.
- Adopt the Smart Cities Program in its entirety and incorporate the “at least 80% buildings (in redevelopment and greenfield) should be energy efficient and green buildings” criterion. States and municipalities (especially where SCM and AMRUT schemes are being actively implemented) should ensure resource efficiency through GRIHA adoption.
- Mandate GRIHA adoption for government projects. For example, Maharashtra PWD had instructed all new buildings to be GRIHA compliant and upgraded 300 buildings in the state in 2019 according to GRIHA.

7.2 Incentives and financial support

- Financial or other incentives for developers and occupants should be structured with an objective to provide proportionate compensation for green-building-linked additional costs incurred by a project. The incentive packages should be targeted, consistent, and coordinated at all levels.
- Set up a time frame and mechanism to convert policy incentives into mandatory regulations.
- Support initial investments for green-building schemes, providing innovative financing instruments to projects. For example, increased investment funds may be made available for green-building developers at reduced interest rates from allied banks and other financial institutions.

7.3 Ease of processing incentives and benefits

- Disseminate information in print and electronic media to enhance outreach. Ensure all information is made available through a regularly updated official website. Notices should be displayed on the main webpage and office bulletin boards. An internal mechanism for systematic website maintenance may be set up.
- The incentive model should clearly mention the project cycle and stage(s) at which the linked incentives shall be released. The timelines and penalty clauses should be mentioned, and timely incentive release should be ensured.
- Set up a dedicated Environment Cell and Review Committee comprising experts and/or a GRIHA official with clearly stated responsibilities. This expert network may act as a single point of contact for all green-building-related queries and liaison between various departments for releasing incentives.

7.4 Awareness generation among all stakeholders

- Create awareness about the prolonged and long-term benefits of green construction by developing relevant resource material.
- Invest in capacity-building programs for the public and the training of staff responsible for implementing green-building schemes. Ensure their inclusion in the annual budget and timeframe.
- Maintain clarity and transparency in the incentives/processes offered/followed to ensure more uptake by citizens.
- Conduct annual events and award local achievements in the green-building field.
- Simultaneous efforts required in building markets for energy- and resource-efficient technologies, skills, and building materials.

8. Conclusion

This paper examines select institutional mechanisms for incentivising green-rated projects. Project-level implementation mechanisms to propose recommendations that may be adopted by various municipal bodies were studied. Currently, only 25/100 smart-city proposals include GBRs to achieve essential SCM goals. Based on feedback from certification agencies, project proponents, and government officials, information dissemination on institutional mechanisms for municipal bodies to integrate GBRs within their existing framework is vital. GBRs will ensure effective ground implementation of resource efficiency and support upcoming smart cities to fulfil CSCAF requirements.

Implementation of the proposed recommendations provides municipal bodies a huge opportunity to strengthen their initiatives in the green-building domain and report CC mitigation, adaptation, and resilience measures to CSCAF using GRIHA parameters. These recommendations can also serve as useful guidelines for local-government agencies in other developing countries for implementing and encouraging green initiatives in the residential building sector for CC mitigation and adaptation.

CSCAF, which incorporates GBRs (including GRIHA) to assess municipal bodies' performance, will also benefit and be able to report achievements of municipal bodies at national and international levels only when data are collated at the local level. Setting up eco-cells with the GRIHA Council's support will facilitate data collection and reporting, thereby establishing a vertical connect while ensuring ground implementation.

Development authorities that are currently ineligible under SCM but are taking initiatives on green buildings are encouraged to express their interest in being included in SCM. Similarly, identified smart cities that have adopted several green-building measures are encouraged to report the same for effective and transparent implementation of national policies and commitment to CC mitigation, adaptation, and resilience.

This study had some limitations in, primarily in terms of data and information collection:

- (1) Project proponents are hesitant about sharing financial and building-performance data.
- (2) Access to municipality/local-body data is challenging as information in most cases is neither digitised nor easily accessible.
- (3) Information about GBR-linked incentives in the remaining states/UTs is inaccessible; collecting such information physically was extremely difficult during 2019–2021 because of COVID-19-mandated travel restrictions.

Further study on building performance and cost analyses of GRIHA-rated projects is required to facilitate appropriate design of incentives according to local institutional mechanisms.

Data availability statement

Extended data

Open Science Framework: 2020_0825_Green Building Policies and Initiatives and working document.

<https://doi.org/10.17605/OSF.IO/MX74U> (Kochhar, 2022)

This project contains the following extended data:

2020_0825_Green Building Policies and Initiatives_working document:

Chronology

List of States and UTs

Smart Cities

Analysis

Savings and cost_rating systems

SCAF indicators

Haryana incentives

Incentive wise_Municipal level

Projects-Rating data

Ministry wise_Central level

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

Author contributions

Priyanka Kochhar: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; Namrata Mahal: Data Curation, Formal Analysis, Writing – Review & Editing; Sanjay Seth: Resources, Supervision, Writing – Review & Editing; Mandeep Singh: Resources, Supervision, Writing – Review & Editing.

Acknowledgements

We are grateful to all local body officials for their valuable inputs and useful discussions. We thank Ms. Shibani Choudhary, Project Officer at GRIHA Council for providing technical support. We also thank all promoters and consultants for their inputs on the green residential projects.

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Version 1

Reviewer Report 19 April 2022

<https://doi.org/10.5256/f1000research.120255.r126429>

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Walaa S.E. Ismaeel

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The paper discusses the role of GRIHA green building rating system to catalyze climate change mitigation and adaptation. The topic is interesting, nevertheless, the paper is poorly prepared. It is rather a report than a scientific manuscript. The aim is not properly defined and it was not clear how the authors intended to address it quantitatively.

- The abstract is rather generic. Revise the abstract to be concise, briefly summarizing the aim, objectives, method, results and conclusion of the study. Currently the abstract is long and some of the text can move to the introduction.
- Keywords: Revise keywords, they are too many
- The method is not properly explained and it is not clear how did it get to the results.
- The discussion and conclusion should be also revised to pinpoint the novelty of the study compared to other studies.

Is the background of the case's history and progression described in sufficient detail?

No

Is the work clearly and accurately presented and does it cite the current literature?

No

If applicable, is the statistical analysis and its interpretation appropriate?

No

Are all the source data underlying the results available to ensure full reproducibility?

No

Are the conclusions drawn adequately supported by the results?

No

Is the case presented with sufficient detail to be useful for teaching or other practitioners?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Green building design and assessment

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 21 February 2022

<https://doi.org/10.5256/f1000research.120255.r122674>

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Hina Zia

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The article attempts to critically examine and push forward the possibilities offered by a whole range of institutional mechanisms for incentivizing GBRS (with a focus on a specific rating system GRIHA) for catalysing climate-change mitigation and adaptation in India. The authors have touched upon a very important aspect of making the building sector 'green' and thus contribute to NDCs. The literature review and coverage of the variety of policy tools at local and state levels is comprehensive. There are however, few minor suggestions to further achieve the intended objectives.

1. It is suggested to improve the section on methods, specifically the part on details as to how many types and numbers of stakeholders from various geographies were selected for interviews. What specific inputs were intended to be received by interviewing these stakeholders? 'Structured questionnaire' is mentioned in the text but there is no further information available on the kind of questions asked, variety of stakeholders' interviewed, number of such interviews, etc.
2. An attempt to distinguish between advantages/challenges of policy tools such as mandatory codes and voluntary GBRS (including GRIHA) in Indian context (based on the experiences of various states/cities already covered by authors) would be very helpful.
3. Further deliberation on the key lessons learnt which has not been covered by any other studies (like WRI 2020 report) can help local government and state governments to take further necessary action. For instance, the authors have conducted structured interviews with few government entities and private developers. Insights from both supply and demand side of green buildings would add further value to this article.

4. CSCAF 2.0 intends to scale the assessment tool from 100 smart cities to 500 cities. The authors may accordingly modify the article in the relevant section.

5. All Tables and Figures need to be properly 'sourced' as per any APA norms. Avoid repetitions, for instance, Table 2 has several repetitions.

Is the background of the case's history and progression described in sufficient detail?

Yes

Is the work clearly and accurately presented and does it cite the current literature?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Is the case presented with sufficient detail to be useful for teaching or other practitioners?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Green buildings, Climate Change and resilience, Urban regeneration, Ekistics, Urban ecology, economics of green buildings

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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