NET-ZERO BUILT ENVIRONMENT

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Jana Urban Space works towards transforming the quality of life in urban India through the streams of urban planning and design, across both policy and practice. Placing community and environmental sustainability at the heart of design, Jana Urban Space works on policies on land titling, spatial reforms, and street design guidelines, as well as regional plans, masterplans, and neighbourhood-level plans. The organization also focuses on the improvement of road infrastructure (Tender S.U.R.E.), rejuvenation of public spaces (markets, bus stands, lakes, parks, heritage and community centres), and the architecture of affordable housing.

NET-ZERO BUILT ENVIRONMENT

Critical pathways for a sustainable future

June, 2025

Prepared by
Jana Urban Space Foundation

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Source: Unsplash

List of acronyms

AAC	*Autoclave Aerated Concrete*
AAQ	*Availability-Affordability-Quality*
BMTPC	*Building Materials and Technology Promotion Council*
CII	*Confederation of Indian Industry*
CPWD	*Central Public Works Department*
DSR	*Delhi Schedule of Rates*
ECBC	*Energy Conservation Building Code*
EEV	*Energy Efficiency Value*
ENS	*Eco Niwas Samhita*
EWS	*Economically Weaker Sections*
FGD	*Focus Group Discussion*
GHG	*Greenhouse Gas*
LIG	*Lower Income Group*
MIG	*Middle Income Group*
MNRE	*Ministry of New and Renewable Energy*
MoHUA	*Ministry of Housing and Urban Affairs*
MoP	*Ministry of Power*
MoRTH	*Ministry of Road Transport and Highways*
PMAY	*Pradhan Mantri Awas Yojana*
PMSGY	*PM Surya Ghar: Muft Bijli Yojana*
RACHNA	*Residential Affordable Comfortable Housing through National Actions (under PMAY-U)*
RETV	*Residential Envelope Transmittance Value*
RTS	*Rooftop Solar*
SED	*State Energy Department*
SoR	*Schedule of Rates*
SRI	*Solar Reflectance Index*
ULB	*Urban Local Body*

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1. Introduction

1.1 India's affordable housing sector

INDIA'S SUSTAINABLE DEVELOPMENT FUTURE HINGES ON THE AFFORDABLE HOUSING SEGMENT.

India is at a critical inflection point where urbanization and its impact on climate are converging. India's urban population is expected to rise from 31% in 2011 to 38.2% in 2036, accounting for an additional 218 million population (National Commission on Population, 2020). As per the United Nations, India is expected to be more than 50% urban by 2050 (World Urbanization Prospects, 2018).

This, in turn, will lead to an increased demand in infrastructure to house and service the additional urban population, with the highest demand expected to be in residential floor space. The urban residential sector was adding 0.52 billion sqm floor space annually in 2020. By 2050, this is expected to go up by 82%, adding 0.95 billion sqm annually (National Institute of Urban Affairs & RMI, 2022). In a business-as-usual (BAU) scenario, energy consumption from this will increase threefold, and carbon emissions will quadruple. Therefore, it is crucial to ensure that all new building stock, expected to last for the next five decades, is built in a climate-conscious manner to reduce energy consumption and carbon footprint of the built environment, especially residential buildings.

Additionally, this has to predominantly address the economically weaker sections (EWS) and low-income groups (LIG). The Confederation of Indian Industry (Confederation of Indian Industry & Knight Frank, 2024), states India's urban housing demand for 2030 to be 22.2 million units, of which 95% (21.1 mn units) are from the affordable housing segment. This implies that the bulk of residential development in Indian cities are required to be affordable in nature.

THE NEED FOR CLIMATE-SENSITIVE AFFORDABLE HOUSING GOES BEYOND REDUCING EMISSIONS.

Considering that 50% of GHG emissions from the residential sector comes from heating and cooling needs, EWS and LIG segments are also impacted disproportionately by rising energy demands. Dong et al. (2021), highlights that Heating, Ventilation, and Air Conditioning (HVAC) systems are energy and carbon intensive, and unaffordable for low-income households. Studies also show that poorly insulated affordable housing units pose a higher risk of exposing inhabitants to prolonged energy poverty (Chen & Feng, 2022).

This study claims that ensuring sustainable development for all new building stock, and achieving India's target of reducing 45% GHG emissions by 2030 and Net Zero by 2070 is only possible if the needs of the affordable housing segment are addressed.

There is an urgent need for an integrated approach to decarbonisation in cities. This study explores the existing pathways for decarbonization in the Indian cities, specifically to –

- Map and analyse all available critical net-zero pathways and instruments Indian cities.
- Acknowledge that policy is only as successful as it's implementation on ground; thus to map implementation frameworks of key regulations, policies, schemes, and market instruments to measure implementation efficacy, and gaps.
- Measure the affordability of existing pathways, to capture their applicability in Indian cities' most vulnerable yet one of the fastest growing segments – the affordable housing sector.

70% of GHG emissions come from cities in India.

37% of this comes from the built environment.

50% of GHG emissions come from heating and cooling needs.

From 2020- 2050, the urban residential sector is expected to add **0.95** billion sqm annually, leading to **4x** emissions and **3x** energy consumption.

65% Households in India are energy poor. In urban India, this number stands at **28%**.

Cooling demand in India is projected to grow at **15–20%** annually, with space cooling expected to account for **45%** of peak electricity demand by 2050.

Image source: Unsplash

1.2 Net zero pathways in the built environment

Currently the building and construction sector contributes to nearly 40% of annual GHG emissions globally. In India, this number stands at 32% (India Third Biennial Update Report to UNFCCC, 2021). Within this, 60-65% comes from operational emissions – primarily from energy use for heating and cooling needs (National Institute of Urban Affairs & RMI, 2022). Of the 35-40% embodied emissions, the most significant portion comes from using energy-intensive building materials and construction processes. To understand the pathway to equitable built environment decarbonisation, we look at this lifecycle detailed in *Figure no. 1*, and analyse key nodes of intervention.

This report identifies five pathways of emission reduction in the built environment –

reducing operational emissions through

(i) clean energy transition (ii) energy-efficiency

reducing embodied emissions through

(iii) sustainable materials (iv) sustainable construction technologies, (v) building retrofit.

While the larger research reviews all five pathways, this report focuses on the first four pathways.

Life cycle stage	% emissions
Manufacturing	**23-34%**
Construction	2-4%
Building use	**60-65%**
End of life	1-6%
Beyond the boundary	N/A

Table no. 1. Life cycle emissions of a typical building

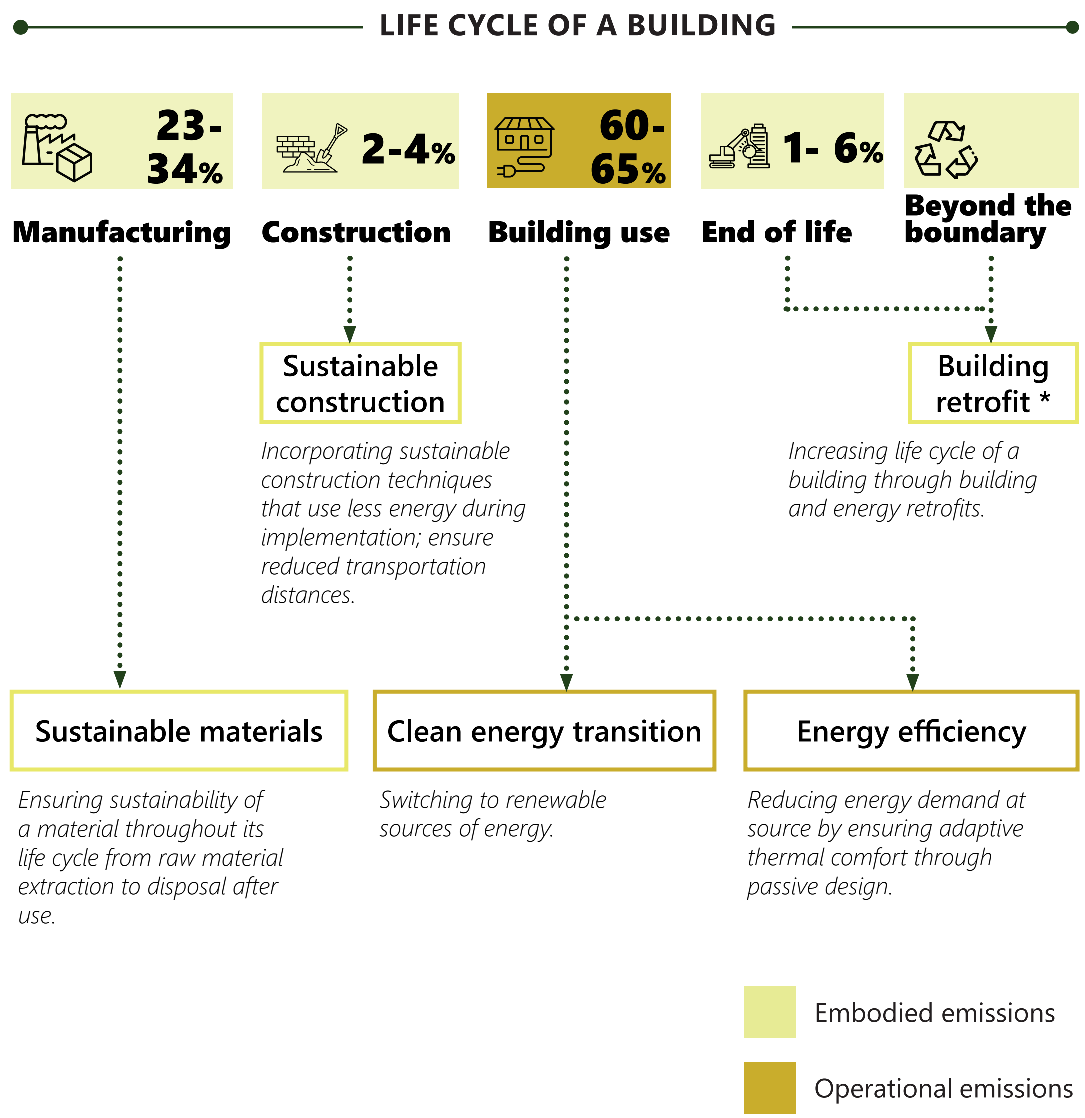


Figure no. 1. Life cycle of a building

Landscape study

1.3 Scope of study

Way forward

01

Literature review of existing regulations/ laws/ policies/ schemes on energy and emission reduction in affordable housing

02

Conduct stakeholder meetings to understand implementation challenges and validate learnings from field experts and market agents

03

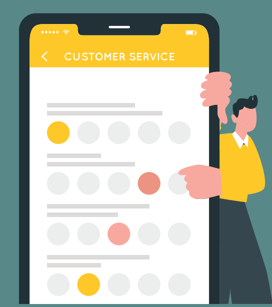
Conduct AAQ analysis for the net zero pathways identified and identify key nodes of change

04

Simulate design scenarios for affordable housing based on the findings of the landscape study

05

Conduct FDGs with end users on operational/ maintenance challenges and proposed design solutions in identified cities and communities



06

Co-curate guidelines to achieve net-zero affordable housing and low carbon neighbourhood plans in select cities

Prepare strategy for net-zero adoption in the larger built environment

Source: Pixabay

2. Methodology

2.1 The Availability-Affordability-Quality framework

2.1.1. Overview

This study hypothesizes that while numerous solutions exist to mitigate operational and embodied emissions in the built environment in India, none are tailored specifically for the affordable housing sector.

The study examines existing the identified pathways for emission reduction through a threefold lens – (a) Availability of existing solutions and policy/regulations/instruments through which solution is made available at scale, (b) Affordability of the solution, including incentivisation for LIG segment, and (c) Quality of solution with respect to emission reduction over complete life-cycle. *Figure no. 3* gives a gist of the primary research questions.

AVAILABILITY

- Is a solution **available** for a specific pathway? If yes, then how is it made available at scale?
- Does the implementation mechanism of solutions converge with affordable housing policies?

AFFORDABILITY

- Is the solution **affordable** to EWS and LIG consumers?

QUALITY

- What is the **quality** of the solution with respect to emission reduction?
- Does achieving affordability impact the quality of the solution?

Figure no. 2. AAQ research questions

2.1.2. Framework

The Availability-Affordability-Quality (AAQ) framework is used to analyse regulatory and policy instruments across built environment, affordable housing, and net zero pathways. The AAQ framework was developed to review the efficacy of existing solutions in the context of affordable housing, and exploring if affordability comes at the expense of quality. The study applies a mixed method approach of analysis applied against the AAQ framework. Specific research questions for the AAQ framework along with the type and method of analysis applied to explore those questions are described below.

AVAILABILITY

	Research questions	Method of analysis	Type of analysis
1	Is a solution available for a specific pathway? If yes, then how is it made available at scale?	Identification and mapping of regulations, policies, schemes, guidelines, market instruments that solve for the identified pathway	*Qualitative*
2	Does the implementation mechanism of identied solutions converge with affordable housing policies/ implementation?	Comprehensive flowchart of implementation mechanisms of solutions cross-examined against affordable housing policies.	*Qualitative*

2

AFFORDABILITY

Research questions	Method of analysis	Type of analysis
Is the solution affordable to EWS and LIG consumers?	Bill of Quantities comparison of a conventional affordable housing unit vs an affordable housing unit.	*Quantitative*
	Consumer surveys on operational/ maintenance challenges of solution	*Qualitative*

QUALITY

Research questions	Method of analysis	Type of analysis
What is the quality of the solution with respect to emission reduction?	Comparative analysis of impact metrics for all pathways to identify conflicts in quality of output.	*Quantitative*
What is the quality of the solution with respect to emission reduction?	Consumer surveys on operational/ maintenance challenges of solution	*Qualitative*

Figure no. 3. AAQ framework

2.2 Boundary conditions

2.2.1. Housing affordability

The Ministry of Housing and Urban Affairs, India identifies 3 income groups under the affordable housing segment. The study focuses on the EWS and LIG income segments.

Income group	Annual household income (in INR)
Economically Weaker Section (EWS)	**up to 3,00,000 INR**
Low Income Group (LIG)	**between 3,00,001 – 6,00,000 INR**
Middle Income Group (MIG)	**between 6,00,000 – 9,00,000 INR**

Table no. 2. Income groups and criteria for housing

As per the Task Force Report on Promoting Affordable Housing, (Ministry of Housing & Urban Poverty Alleviation, 2012), the desirable housing price to income multiple for affordable housing should not be more than 5. However, housing price is dependent on land price and construction cost. Since land prices are highly variable based on geography, and outside the purview of this study, this study focuses on affordability of construction cost.

The study applies a Bill of Quantities comparison, considering a conventional affordable housing unit of 30 sqm carpet area, with an RCC frame construction, with burnt clay brick walls of 250 mm thickness, and unplastered RCC slab roofing. The construction cost for the base case is 1101190 INR overall, or 25700 INR per sqm. This corresponds with the average cost of construction for a 30 sqm basic unit across India (Construction Cost Calculator for House, n.d.).

2.2.2. Scenarios for analysis

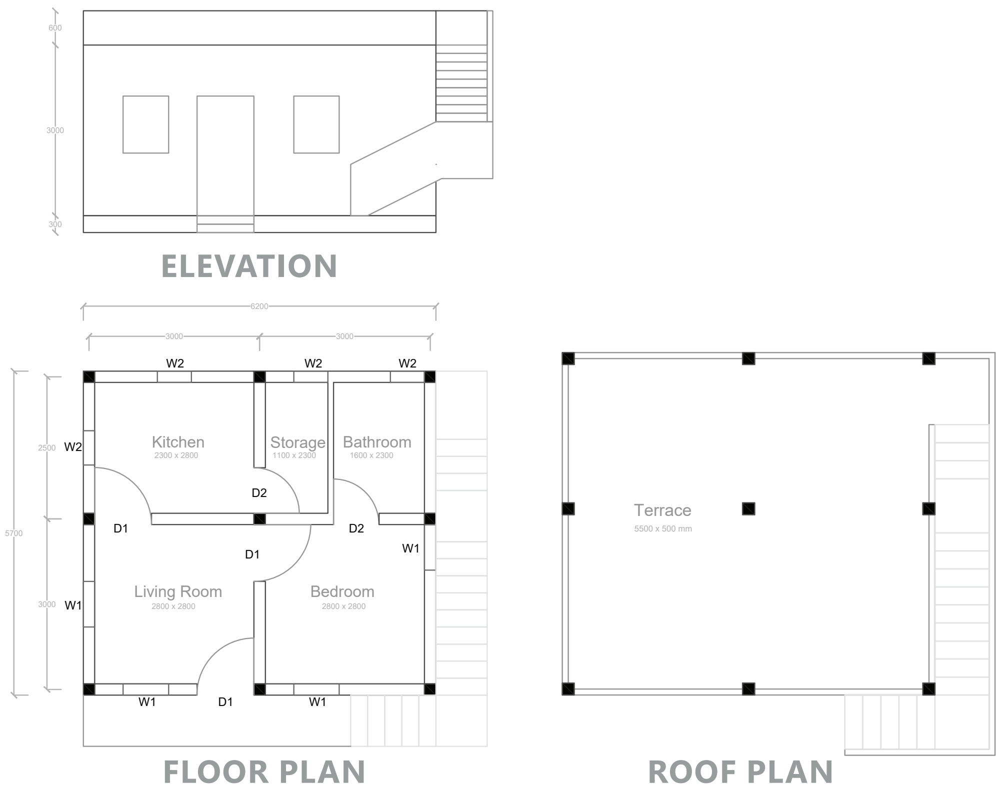


Figure no. 4. Typical plan and section for an independent affordable housing unit of 30 sqm carpet area

- Construction type: RCC frame structure with burnt clay brick walls of 230mm thickness; unplastered RCC slab roofing.
- Carpet area: 29.05 sqm
- BUA: 43.54 sqm
- Plot area: 657 sqm
- Columns: 200 X 200 mm
- Beam: 200 X 250 mm
- Wall area: 103.2 sqm

Individual affordable housing unit

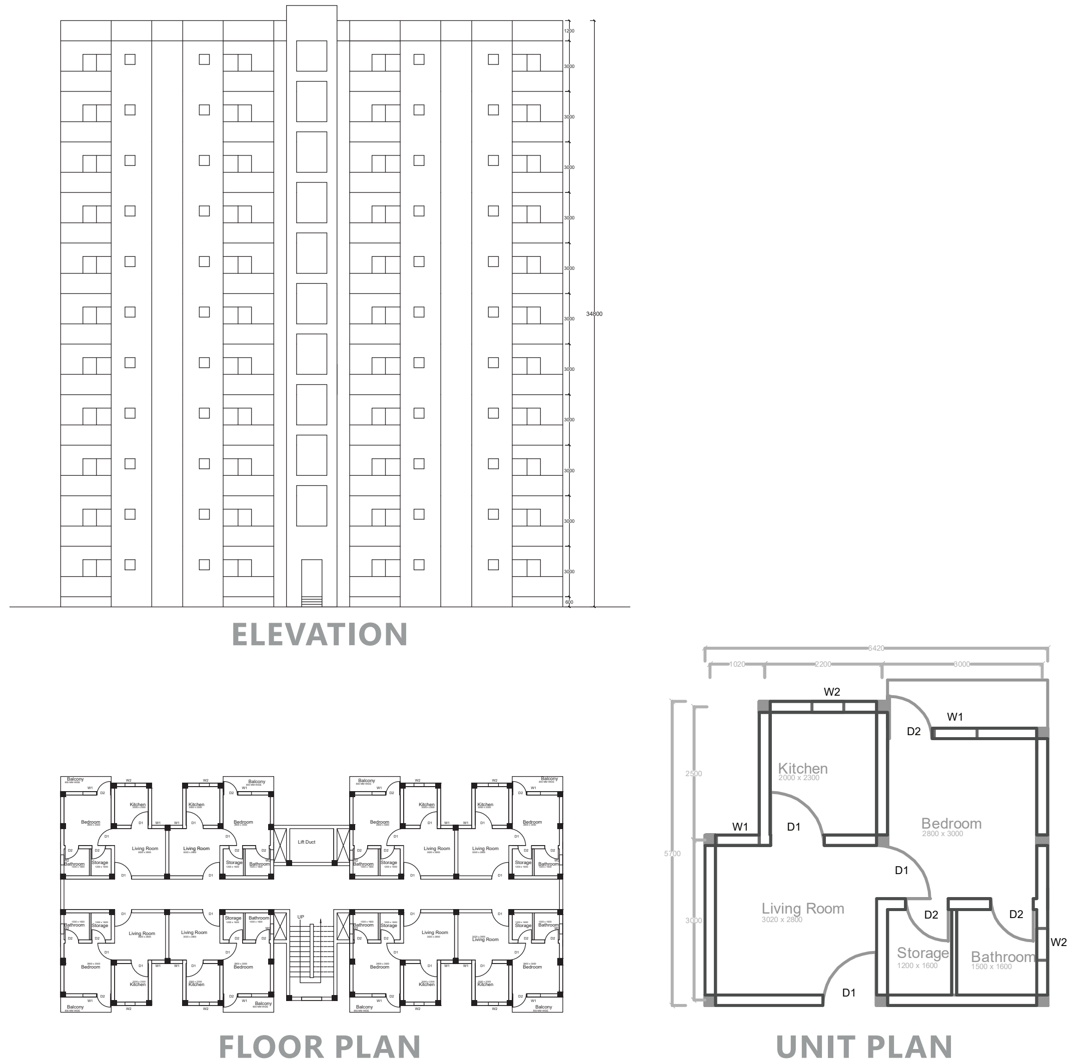


Figure no. 5. Typical plan and section for a mass affordable housing complex of 100 units.

- Construction type: RCC frame structure with burnt clay brick walls of 230mm thickness; unplastered RCC slab roofing.
- Carpet area (per unit) : 28.47 sqm
- no of floors: G+9,
- total no of units = 80
- Total BUA 2843.2 sq m
- Plot area: 1047.34 sq m
- Columns: 300 X 300 mm
- Beam: 300 X 300 mm
- Wall area (per unit): 103.2 sqm

Mass affordable housing


Source: Pixabay

3. Findings

Finding 1. Existing solutions rarely extend to the Affordable Housing Segment.

In the Mumbai Metropolitan Region, the average price of a residential unit under 30 sq. m. increased by 55%, from INR 1.7 million in 2019 to INR 2.6 million in 2024

Knight Frank Research, 2024

Rising land prices in metropolitan cities have made affordable housing, particularly for the Economically Weaker Section (EWS), increasingly unattainable. Despite high housing demand and a large EWS population in these regions, there exists a significant gap between eligibility criteria and actual affordability for intended beneficiaries (Knight Frank Research, 2024). For example, in the Mumbai Metropolitan Region, the average price of a residential unit under 30 sq. m. increased by 55%, from INR 1.7 million in 2019 to INR 2.6 million in 2024, widening the affordability gap.

Transitioning to renewable energy through Rooftop Solar (RTS) installations also imposes a significant upfront financial burden on EWS households. The estimated installation cost of INR 130,000 per unit translates to 18–44% of the annual household income, depending on subsidy coverage (refer *Table no. 3*).

Recommended construction materials compound cost barriers. We did a comparative analysis considering the base case as an RCC framed structure with burnt clay brick walls and unplastered RCC slab roofing. Fly ash blocks are one such alternative walling materials that can reduce the overall cost by 4.5% but do not satisfy RETV benchmark recommended by the nationally adopted Eco Niwas Samhita (ENS) code on energy conservation (refer *Table no. 13 on page 99),* while thermally comfortable Autoclaved Aerated Concrete (AAC) blocks, which are widely adopted across India, have been shown to drive up overall unit construction costs by approximately 11%. A SoR cost comparison as per DSR shows that **it is 300 times more expensive to wall an individual EWS house with C&D waste blocks**.

WORKS *(material + labour)*		Quantity	Unit	Rate (Tamil Nadu)	Rate (Uttar Pradesh)	Rate (Delhi)	Amt. (Tamil Nadu)	Amt. (Uttar Pradesh)	Amt. (Delhi)	Amt. (Tamil Nadu)	Amt. (Uttar Pradesh)	Amt. (Delhi)
							For 1 cum wall			*For 1 AHU (wall volume = 25.8 sqm)*		
230 x 110 x 75 mm	Brickwork - Class II masonry					4590.00	6304.00	5272.44	4975.87	1,62,643.19	1,36,028.82	1,28,377.35
600 x 200 x 200 mm	Fly Ash (Fl AG)	449.45	1000 no.	6795.00	6200.00	3950.00	5692.57	5425.21	4414.18	1,46,868.41	1,39,970.49	1,13,885.93
400 x 200 x 200 mm	AAC	1.00	cum	3404.77		2650.00	6044.04	NA	5289.27	1,55,936.00	NA	1,36,463.00
	Precast C&D waste concrete blocks	60.84	1000 no.			25150.00	NA	NA	1532698.44	NA	NA	3,95,43,620.00

Table no. 3. Schedule of Rates based cost comparison of walling materials

> **Key barrier for solar power is very low payback on tariff for residential buildings and long payback period of 6 yrs.**
>
> *Solar Expert, JMK Analytics.*

For roof, adding high SRI materials like white paint, white tiles on the RCC slab increases thermal comfort with marginal cost increase. Switching to filler slab roofing can satisy ENS benchmarks for U value and SRI, also saving on an additional 3.5% of the cost base.

Under State affordable housing schemes, developers are given an additional 5-10% Floor Area Ratio (FAR) and tax rebates for buildings certified under green rating systems such as GRIHA and LEED. They are mostly state-driven and vary widely. For e.g. Rajasthan's Mukhyamantri Jan Awas Yojana 2015 offers incentives like Land Use Conversion Fee waivers and FAR up to 2.25 for 100% EWS and LIG projects, mandating fly ash bricks and rainwater harvesting. Uttar Pradesh provides a base FSI of 2.5 plus 5% extra for GRIHA-certified projects over 5,000 m^2 (full list in Annexure, *Table no. 14 on page 100*). But this may be insufficient for an overall cost viability.

A typical cost breakdown is as follows:

COST COMPONENT	Share (%)
Construction (Materials & Labor)	50-60%
Land Cost	10-20%
Administrative & Approval Charges	5-10%
Services, Design & Misc.	5-10%
Profit Margins	5-10%

With margins as low as 5%, even small cost increases for green certification seem unviable, especially as low-income housing sees limited immediate returns from such measures.

Green certifications also come with incremental costs and complexities.

3-Star GRIHA: ~3.1% cost increase; payback in 2–7.5 years.

- 4-Star GRIHA: ~7–10% cost increase; up to 40% energy savings.
- 5-Star GRIHA: ~9.4% cost increase; payback in 2.3–9.1 years.

Additional certification fee of ₹2.5 lakh, valid for five years, with complex renewal requirements.

Implementation also remains limited because the main financial and operational benefits of green buildings such as energy and water savings are accrued by the occupants, developers have little incentive to incur the higher upfront costs of certification unless buyers are willing to pay a premium for green features.

This investment threshold, in the absence of clear financing pathways or guaranteed performance returns, stands as key deterrant for affordable housing developers to adopt such practices.

CASE STUDY #1

COST-BENEFIT ANALYSIS OF A SVA-GRIHA RATED GREEN RESIDENTIAL BUILDING

LOCATION

Bhuvaneshwarinagar, Bangalore

TYPOLOGY

Residential Building G+4

STUDY

The green building was evaluated against a conventional one based on cost, payback period, energy efficiency, passive design, materials, and water and waste management.

FEATURES:

The green building incorporates climate-responsive architectural design, strategic window placement, shading devices, and high-performance glazing to reduce heat gain.

Sustainable materials like Porotherm blocks, PPC cement, recycled steel, and low-VOC finishes were used to lower embodied energy.

Energy systems include a 12 kW solar PV setup, solar water heaters, and LED lighting with low power density. Water efficiency is achieved through rainwater harvesting (1.15 lakh litres/year), low-flow fixtures, and vermicomposting.

The design supports a sustainable lifestyle with optimized space (29.1 m^2 per person), access to public transport, and infrastructure for cycling and EVs.

KEY OBSERVATIONS:

Green building was ~8.65% costlier initially (due to added sustainable features).

Despite this, its base construction cost was lower due to reduced built-up area and efficient planning.

Payback period of 9.7 years makes it a viable long-term investment.

Box number. 1. Source: https://www.irjet.net/archives/V7/i6/ICRTST-2020/IRJET-V7I603.pdf

3

Finding 2. Solutions existing in isolation can be misaligned with broader goals.

AAC blocks, which are superior in terms of RETV values, cost higher and has a significantly high EEV.

RECOMMENDED CONSTRUCTION MATERIALS ARE OFTEN SUSTAINABLE, AFFORDABLE, OR THERMALLY COMFORTABLE – BUT RARELY ALL THREE AT ONCE.

Materials that meet the ECBC thermal performance benchmark of less than 15 W/m^2, such as AAC blocks can rise up construction costs by 11% than conventional materials such as burnt bricks. This price gap makes them difficult for EWS consumers to choose in their housing projects.

To accommodate for affordability, rating systems like IGBC's NEST, and NEST+ lower thermal performance requirements. In NEST+, the wall assembly U-value threshold is relaxed from 1.2 W/m^2K (as per ENS) to around 1.8-2.0 W/m^2K, significantly reducing insulation quality. RACHNA guidelines, developed under PMAY, also lacks U-value and Solar reflectance Index (SRI) specifications. To bridge this gap, affordable insulation such as glasswool/rock wool, coconut coir panels can be integrated with the hollow blocks but their energy saving potential needs to be evaluated empirically.

IGBC's recommendations for construction materials, based on GreenPro eco-labelled products rely on comparitive performance of materials rather than a universal baseline. These trade-offs highlight that materials deemed green or cost-effective may not ensure adequate thermal comfort.

ENS benchmark

Wall	RETV (W/m2)	≤ 15 W/m2
Roof	U value (W/m2)	≤ 1.2 W/m2
	Solar Reflectance Index SRI	>0.6

Table no. 5. ENS benchmarks for energy efficiency

	CASE - WALL	Case 1 - Base case	Case 2	Case 3	Case 4	Case 5
		Burnt clay brick + cement plaster	CSEB	Fly ash block + cement plaster	AAC block	Solid concrete block + cement plaster
Wall	Difference in cost	0.00	-20353.27	-49234.97	119323.06	117,390.21
	Difference in RETV	0.00	2.27	-0.28	-4.27	8.86
	Difference in EEV	0.00	-15037.46	-10209.91	-759.95	-10484.92
Roof	Difference in EEV	0.00	17.71	26.18	-438.87	
	Difference in U value	0.00	0.00	0.00	-0.38	
	Difference in SRI	0.00	59.00	49.00	0.00	
	Difference in cost	0.00	15991.82	38658.55	11458.26	
		RCC slab, unplastered	RCC slab + white coating (1 coat)	RCC slab + white cement tile	RCC filler slab, unplastered	
	CASE - ROOF	Case A - Base case	Case B	Case C	Case D	

Table no. 4. Construction cost and quality differential comparison of recommended materials

An exception to this is cool roofs such as white coatings, broken white tiles on RCC slabs that can provide higher thermal comfort with marginal increase in costing. They are also a viable retrofitting solution.

CASE STUDY #2

COOL ROOFS AS AN AFFORDABLE, SUSTAINABLE AND THERMALLY COMFORTABLE SOLUTION

LOCATION

Delhi, India

STUDY

A cool roof is one that reflects most of the incident sunlight and efficiently emits some of the absorbed radiation back into the atmosphere, instead of conducting it to the building below. As a result the roof literally stays cooler, with lower surface temperatures, keeping the building at a cooler and more constant temperature.

OBSERVATIONS: While the ENS recommends a SRI > 0.7 for roofs, simple and cost effective solutions such as white coatings and broken mosaic tiles can achieve an SRI between 0.9-1.0.

RESULTS: Cool roofs with high SRI values can reduce roof surface temperatures by up to 30–40°C compared to conventional dark-colored roofs.

Reduction in cooling energy consumption by upto 20–30%, depending on the building type and climatic conditions.

Some cool products cost less than traditional materials, some cost up to 20% more.

Higher maintenance savings with an average 20 percent savings on air conditioning costs make cool roofing a better bargain over the long term.

Cool roofs help mitigate the intensity of the UHIE by reducing heat absorption and transfer to the surrounding air.

Applying cool roof coatings, such as solar-reflective paints or membranes, is relatively low-cost and can be easily integrated into both new constructions and retrofits.

	Approximate cost per sqm	Pay back time
Simple White Paint-Exterior Grade	Rs. 80-100	≤ 1 yr
Tiles/ mosaic	Rs. 300	≤ 1 yr
Reflecive roof coatings	Rs. 40-50	≤ 1 yr

Box number. 2. Source: Cool Roofs for Cool Delhi: Design Manual

A study published by IIT Kharagpur reveals that city-wide rooftop PV panels deployment can raise daytime temperatures in urban areas by up to 1.5 °C.

IN HOT INDIAN CLIMATES, POORLY PLANNED RTS INSTALLATIONS CAN UNINTENTIONALLY LEAD TO URBAN HEAT ISLANDS

Solar panels can also affect the thermal characteristics of roofs and floors below. While RTS is encouraged for its low albedo and heat absorbing surfaces, it can lead to more heat being retained rather than converted into electricity. This heat is then released into the surrounding air, raising local temperatures. Additionally, elevated installations creates two hot surfaces- the top of the panels and the underside - enhancing thermal convection and further increasing air temperatures around them. In areas where there are a lot of solar panels, it heats up the surrounding area as well, creating an Urban Heat Island effect. This effect is further magnified by efficiency losses from irregular cleaning.

However, current policy frameworks do not include installation and maintenance guidelines for rooftop solar systems, overlooking thermal comfort at a neighbourhood scale, and possible impacts of waste generation and recycling.

'SUSTAINABILITY' OF A BUILDING MATERIAL IS NOT CONSISTENTLY DEFINED; AND WEAKLY PRIORITISED

Embodied emissions contribute to 35-40% of overall built environment emissions in India (National Institute of Urban Affairs & RMI, 2022). This share is expected to rise to 50%, as the share of operational emissions decline over time (Jain et al., 2023). A large part of this shifting balance between embodied and operational emissions is due to policy focus skewed largely in favour of operational emissions. Studies show that weightage given to the use of green materials in green building rating systems and building codes is 8-9% (Jain et al., 2023). Except the ENS complience tool, none of them include sustainable construction in their mandatory categories. (refer *Table no. 6*)

The absence of a universal benchmark also means that 'green' status is arbitrarily assigned and varies based on origin (e.g., natural, recycled, or local). For example, IGBC's NEST recognizes only GreenPro-labelled products, granting credits for relative improvement without referencing any fixed baseline metric (CII, 2016).

Rating system	Clause	Mandatory points	Incremental points
Eco Niwas Samhita	Non-hazardous waste generated is reused/repurposed/recycled/salvaged (by weight/ volume)	atleast 50%	75% - 1 pts 95% - 2 pts
NEST	Handling construction waste materials	N/A	50% - 1 pts
	Reuse of salvaged/ reused materials	N/A	2.5% - 1 pts 5% - 2 pts
	Use of materials with recycled content		10% - 1 pts 20% - 2 pts
	Use of local materials (by cost) - manufactured within 400km distance		25% - 1 pts 50% - 2 pts
	Use of rapidly renewable building materials & certified wood		50% - 2 pts 75% - 4 pts

Table no. 6. Criteria comparison for sustainable building materials in rating systems

3

Finding 3. Missing communication channels between key actors hinder policy implementation.

ENERGY SCHEMES/ CODES TEND TO LEAVE OUT AFFORDABLE HOUSING FROM THEIR PURVIEW

ECBC (2007) marked India's first national regulatory framework to mandate energy efficiency, has only commercial buildings under its scope. The Eco Niwas Samhita which came out in 2018 shifted the policy focus beyond commercial buildings to address thermal comfort, energy savings, and occupant well-being in the residential sector. ENS 2024 applies to all residential buildings with a minimum connected load of 100 kilowatt (kW) or contract demand of 120 kilovolt ampere (kVA) - which essentially leaves out individual affordable housing and mass EWS housing with <300 units.

The PMAY has drafted the RACHNA guidelines focusing on thermal comfort for affordable housing. However, there is limited evidence on its application, currently implemented in only 6 lighthouse projects across India (Ministry of Housing & Urban Affairs, 2022). Refer *Table no. 7* for the coverage of projects under different policies.

Even penetration of sustainable building materials are disabled by contractual frameworks in state-led affordable housing (more details in Finding 4 of this chapter).

The focus of net zero policies needs to shift towards affordable housing, which is the biggest and fastest growing building market. The success of PMSGY, which superseded National Rooftop Mission, stands as a testiment to this. PMSGY explicitly subsidises residential systems upto 3kW capacity. As of August 2024, the scheme has garnered around 1.3 crore (13 million) registrations and 18 lakh (1.8 million) applications, leading to a total of 3.85 lakh (385,000) installations. This translates to about 1.8GW of new residential rooftop solar capacity, or more than half of India's total, in just six months (Unleashing the Residential Rooftop Solar Potential, IEEFA 2024).

CODE BOOK	Scope of projects covered
ECBC (2017)	Commercial Buildings ≥100 kW or ≥500 m^2 built-up
ENS (2024)	Residential buildings or complexes with min. connected load of 100 kW or contract demand of 120 kVA; or plot area of 3000 m2
RACHNA standard	Residential - affordable housing projects under PMAY-Urban (voluntary)

Table no. 7. Scope of building codes on energy efficiency

There is a lack of convergence of roles between government agencies that plan, oversee and implement codes period of 6 yrs.

Field expert, Prayas Energy Group

STATE DEPARTMENTS AND CELLS NEED TO INTERACT WITH EACH OTHER; WORK WITH COMMON GOALS

Implementation mechanisms chart in *Section 5.4 on page 96* maps the key actors in energy and affordable housing sectors. We can see that the State Urban Development Department, (responsible for making DCRs) and State Energy Department (responsible for energy efficiency, renewable energy) have interact with each other only through the State PWDs. Even within the SEDs- the ENS cell, DISCOMs and SDAs operate in isolation, often with conflicting interests as seen in the previous examples.

State capacities, limited in nature, need to work with common goals and incentives to ensure maximum efficiency.

As of August 2024, PM Surya Ghar has achieved 1.8 GW of new rooftop solar through, translating to over 50% of India's residential capacity in just six months

IEEFA. 2024

TRANSITION TO SOLAR INCENTIVISED AT CONSUMER LEVEL, BLINDSIDES OPERATIONAL CHALLENGES OF DISCOMS

The residential sector is poised for the fastest growth in rooftop solar, but state and market capacities remain underprepared. In Assam, a considerable mismatch between project applications and vendor availability threatens near-term installation growth (IEEFA, 2024). The PMSGY scheme also clashes with state policies offering free electricity up to 100–200 units, which cover 66% of all residences and 100% of affordable housing units, reducing financial incentives for adoption.

While net metering is widely allowed, many DISCOMs are also bound by existing long-term power purchase agreements (PPAs) with coal-based power plants, often spanning 25–30 years. For e.g., in Jharkhand, over 70% of the state's electricity procurement in 2021 was locked into coal-based contracts (Prayas Energy Group, 2022). Setting up large-scale infrastructure such as power lines ans storage facilities can take up to 3-5 years and significant financial capacity of the DISCOMs. Further combined with lack of necessary frameworks such as rate regularization with vendors, guidelines for measuring and billing, implementation of smart metering/ time-of-day (ToD) pricing. This is primarily due to lack of communication channel between the PGYSM cell under MNRE and the State Energy Departments. *Figure no. 6* identifies key gaps in the implementation of rooftop solar.

In Jharkhand, over 70% of the state's electricity procurement in 2021 was locked into coal-based contracts.

Prayas Energy Group, 2022

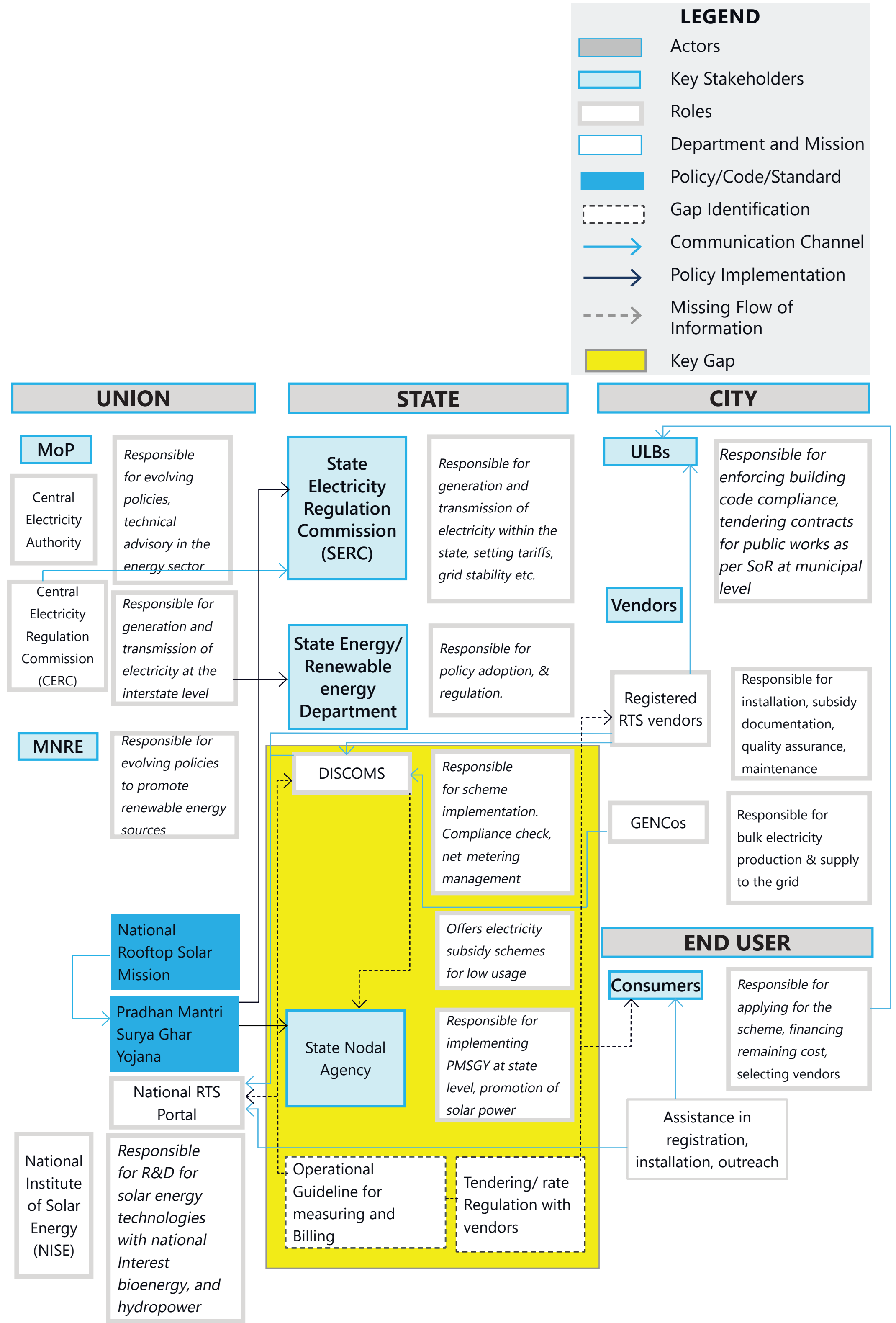


Figure no. 6. Implementation mechanism for rooftop solar policy

POLICY #1 FOCUS

FORMULATED BY:

MoEFCC

YEAR

2025

C&D waste, India's largest solid waste stream at an estimated 150 million tonnes annually, often ends up in landfills. Yet, recycled materials like fly ash, recycled bricks, and concrete have become mainstream largely due to their lower cost and easier availability.

NEW POLICIES LIKE THE **C&D WASTE POLICY** ARE STREAMLINING IMPLEMENTATION PROCESSES

OBSERVATIONS:

The 2016 C&D Waste Rules mandated 10–20% use of recycled products in government projects. The 2025 revision builds on this by introducing Extended Producer Responsibility (EPR), Waste Utilisation Plans (WUP), and a digital monitoring portal.

The policy assigns roles to CPWD, MoHUA, BIS, and MoRTH to incorporate recycled materials into codes, SoRs, and building by-laws. Currently, this mandate applies only to projects above 20,000 sqm, excluding affordable housing developments which typically fall below 460 units.

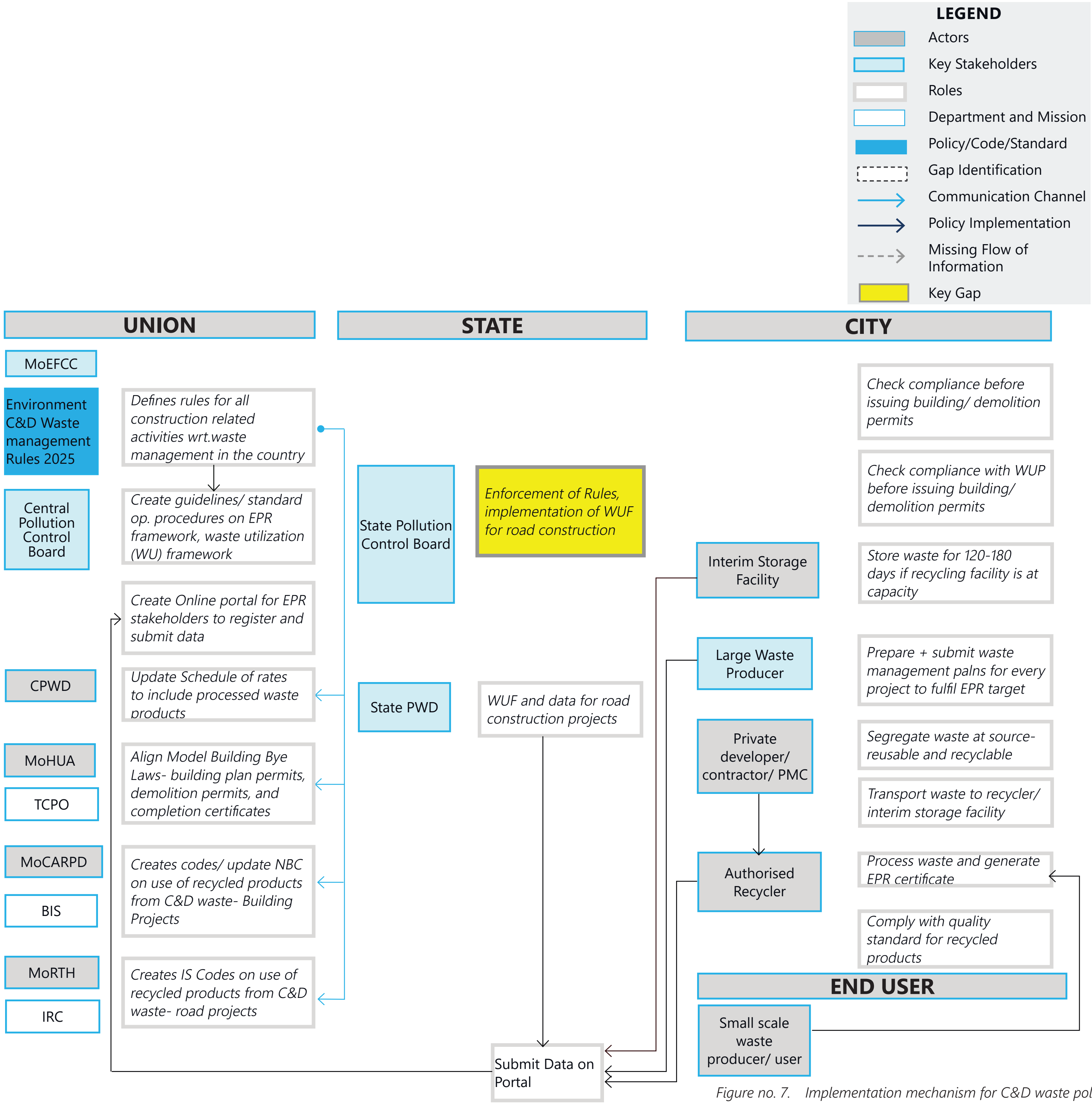


Figure no. 7. Implementation mechanism for C&D waste policies

Finding 4. Despite incentives, regulatory frameworks in the State pose as the key barrier.

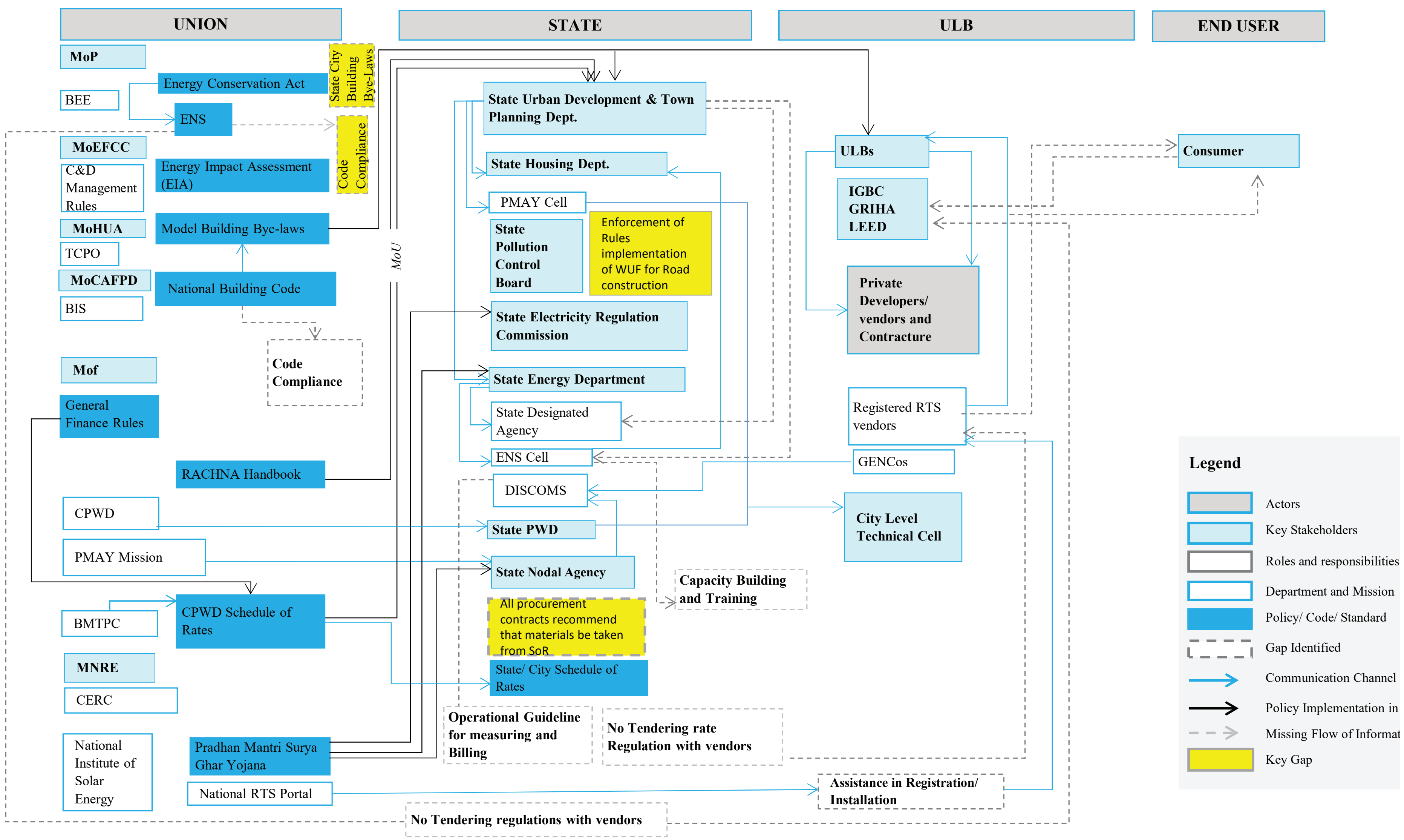


Figure no. 8. Implementation mechanism for energy efficiency and key gaps

While Ministries at the Union level formulate policies, schemes and codes, the authority of enforcing them solely lies with the State. For example, the National Building Code is enforced by the State through Building Bye Laws; URDPFI guidelines through Development Control Regulations (DCRs).

LACK OF REGULATION AT STATE HINDERS EFFECTIVE ADOPTION OF ENERGY EFFICIENCY POLICIES.

Eco Niwas Samhita (ENS), that specifically looks at energy efficiency for residences, in itself is not a legally mandated tool; individual state governments are authorised to mandate it across the state. To date, 17 out of 28 Indian states have initiated the notification of ENS (Bureau of Energy Efficiency & Alliance for an Energy Efficient Economy, 2023). Following chart shows the implementation mechanism of energy codes in the country and key gaps.

In the absence of integration of ENS with Building Byelaws or DCRs, succesful implementation on ground is also affected.

POLICY #2 FOCUS

SOLAR ACCESS PROTECTION UNDER LOCAL BUILDING CODE

LOCATION

Freiburg im Breisgau

TYPOLOGY

High Rise Building

STUDY

Freiburg, known as Germany's "solar city," mandates solar orientation and unshaded roof access in new developments. It require buildings to be positioned for optimal passive solar gain; include solar PV as a standard part of design guidelines.

OBSERVATIONS: The solar access and orientation rules are mandated through: Local building codes that require buildings to be designed for optimal solar gain.
Development plans that prevent overshadowing of solar roofs in new neighborhoods.
Mandatory roof orientation, low building heights, and specific setbacks to guarantee sun access.

RESULTS: Over 70% of buildings in Vauban meet low or net-zero energy standards.

Homes in Vauban use 60% less energy than conventional German homes.

Freiburg reduced CO_2 emissions per capita by over 30% between 1992 and 2018

Box number. 3. Source: Freiburg Climate Protection Report (2020)

> **There's a major skills gap — even where there's intent to go sustainable, there's not enough trained workforce to deliver.**
> *Affordable housing developers from Lucknow*

CURRENT REGULATIONS DISABLE PENETRATION OF SUSTAINABLE MATERIALS AND TECHNOLOGIES TO BE WIDELY USED.

The Compendium of Emerging Construction Technologies (Building Materials & Technology Promotion Council, 2023), presents a list of 69 materials and technologies. The Green Pro Ecolabel (Confederation of Indian Industry, 2025), presents the most comprehensive database of more than 9500 products, materials, and technologies from 450+ companies.

However, under India's procurement regulations, all public works including affordable housing are recommended to use materials listed in the State Schedule of Rates, based on the Central Public Works Department's (CPWD's) - Delhi Schedule of Rates (DSR). (refer *Section 5.3 on page 94*). Currently the process of incorporation of sustainable materials and technologies available in the market into the SoR, as well as regular updation, is unknown. In the absence of a regulated system of including recommendations by BMTPC, BIS, and ENS into the CPWD DSR, the process of ensuring the use of sustainable materials and techniques in affordable housing remains arbitrary.

> **The Green Pro Ecolabel presents the most comprehensive database of more than 9500 products, materials, and technologies from 450+ companies.**
> *(Confederation of Indian Industry, 2025),*

Finding 5. Design solutions that are building-specific may not be feasible for large-scale adoption.

SOLAR PV IS HIGHLY INCENTIVISED, BUT IT MAY NOT BE FEASIBLE FOR MASS HOUSING

Of all the renewable energy sectors in India, solar power has the most potential for on-site generation and is highly incentivised. The Pradhan Mantri Surya Ghar Yojana (PMSGY) provides up to 60% subsidy on residential rooftop solar installations.

As per the Model Building Bye Laws, up to 70% roof area can be used to install PV panels. In a typical EWS individual house, this can generate about 563 units of electricity per month, which is sufficient for the household. But in group EWS housing, due to shared terrace space, the roof panels are able to generate only **28.12%** of the electricity demand per month. Further, the policy only offers subsidy for common facilities. (refer *Table no. 8* for detailed calculation)

This means that despite technical potential and nominal upfront costs, there is no viable policy for EWS group housing consumers to implement rooftop solar. Limited terrace space and conflicting terrace rights also effectively excludes Tier 1 cities, which mostly rely on mass housing models to meet housing demand.

As per the Model Building Bye Laws, a maximum of 70% roof area can be used to install PV panels.

	Total Carpet area (sqm)	Total Built Up area (sqm)	Area for installation of RTS (sqm)	Size of RTS panel (30 units per month capacity) (m)	Max. no of RTS panels on roof	Electricity generated (units)	Solar Electricity usage (units)	Total cost of RTS panels (Rs.)	Percentage of annual household income	
Individual EWS unit	30	42.86	30	1.6 x 1	19	563	200	1,31,250	44	18
Group EWS housing 100 units and 10 units per floor	3000	4285.71	300	1.6 x 1	188	5625	20000	13,12,500	0.04	0.04
		CA is approximately 70% of BUA	***taking 70% of roof area as per MBBL 2016***			*30 units per month capacity*	***electricity demand of a typical EWS house is 200 units***		*without subsidy*	*with subsidy*

Table no. 8. Consumer affordability of PMSGY

WHILE POLICY REVISIONS ARE A LONG-TERM SOLUTIONS, INGENIUS SOLUTIONS EXIST AT THE BUILDING AS WELL AS COMMUNITY LEVEL.

CASE STUDY #3

SOLAR PV INTEGRATED FASCADE DESIGN STRATEGIES FOR HIGH-RISE BUILDINGS

LOCATION

Trondheim, Norway (Latitude 63°25′ N).

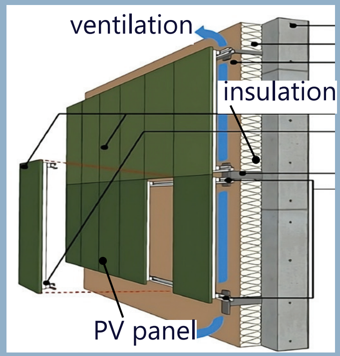
TYPOLOGY

High Rise Building G+11

STUDY This case study highlights the connection between balcony positioning, building envelope and façade-integrated photovoltaic (FIPV) performance in an high-rise residential building.

FEATURES: Low solar elevation angles (sun <10° for over 30% of time).Low frequency of sunny skies in winter.

Behind the panel, there is typically insulation and structural wall.



OBSERVATIONS: If only walls and balconies have solar panels they can cover 30–45% of the annual electricity use. Thus, including the rooftop panels the coverage goes up to 49%

Integrated Solar PV on facades and roofs can cover up to 50% of annual household energy needs.

Potential reduction of nearly 40 tons of CO_2eq emissions annually.

Box number. 4. Functional DEWATS at the Municipal Colony; Source: CDD, India

CASE STUDY #4

SUCCESS OF THE COMMUNITY SOLAR MODEL USING SOLAR TREES

LOCATION

National Salt Satyagraha Memorial, Dandi, India

TYPOLOGY

Solar Power tree

STUDY In space-constrained urban areas, solar trees offer a smart alternative to rooftop or ground-mounted panels. Developed by CSIR-CMERI, they generate clean energy using minimal land—making them ideal for apartments, parks, schools and other public spaces in Indian cities.

FEATURES: Panels are arranged vertically at different angles and heights, mimicking tree branches. This allows sunlight capture from various directions throughout the day.

A 5kW solar tree occupies just 4 square feet of ground space compared to traditional arrays that need 100 times the area for the same output.

Some models include dual-axis tracking to follow the sun, increasing efficiency by 15–20%

which helps maintain performance even in shadow-prone urban environments.

OBSERVATIONS: In Dandi, Gujarat, 41 solar trees were installed to meet the site's energy needs without occupying extensive land. The solar trees have the capacity to generate 182 kWp and meet the energy demand of the entire memorial. The extra energy produced is sold to the Gujarat government, generating a revenue of Rs 1.5L per month.

Box number. 5. Solar Trees for Publioc Spaces Source: IRJMETS, Volume:03/ Issue:04/April-2021

POOR VENTILATION AND DESIGN IN KITCHEN CAN LEAD TO HEAT TRAPPING, WORSENED BY THERMALLY INSULATED WALLS.

In many affordable housing layouts, kitchens are designed as open or semi-open spaces without physical separation from living areas. Cooking in open-plan units significantly raises indoor temperatures when kitchen openings are not aligned with prevailing winds. This results in the transfer of heat to adjacent living areas, increasing discomfort by 3–5°C.

According to the Eco-Niwas Samhita (ENS) 2018, external walls in warm-humid and composite climates must meet a low U-value threshold of 1.2 W/m²K to reduce external heat gain. However, in the absence of targeted ventilation strategies (such as dedicated exhausts or window placement), these thermally insulated walls also limit internal heat dissipation. As a result, heat from cooking becomes trapped within the envelope, raising overall indoor temperatures.

consumer survey, Sayad, B., Osra, O. A., & Qattan, W. S. (2025)

Nights are more uncomfortable than the day, with indoor heat persisting even hours after cooking is done.

CASE STUDY #5

MICROCLIMATE ANALYSIS OF A RESIDENTIAL KITCHEN DURING PEAK SUMMER

LOCATION

Northeastern Algeria

TYPOLOGY

High Rise Building

STUDY

Understanding thermal environment of a residential kitchen during a typical hot summer day relative to air temperature and wind velocity at various points.

OBSERVATIONS: Temperatures rose steadily from 35.6°C at morning, peaking at 37.3°C at 12 p.m., with a second peak between 4–5 p.m 37.8°C.

Airflow remained minimal throughout the day. Opening the window slightly improved ventilation but increased heat gain due to the south-facing orientation, further increasing indoor discomfort in the kitchen.

RESULTS: Without efficient cooling or ventilation measures, heat generated during peak cooking hours remains trapped, leading to discomfort for users. The intensified heat retention and subsequent rise in evening temperature is the result of the thermal properties of the kitchen's envelope materials, which likely absorb and release heat over time, contributing to the residual heat observed.

Box number. 6. Source: Optimizing energy and thermal comfort in residential kitchens: an on-site investigation using thermal imaging, 2025

> **We try to use curtains, soak gunny bags, and even sprinkle water on the roof—anything to beat the heat without spending too much**
>
> *A resident of EWS housing in Lucknow*

YET, INDIAN CONSUMERS ARE READY FOR GREEN BUILDINGS AND GREEN MATERIALS

A report by Xynteo conducted surveys among 1000+ low-mid income respondants across 5 cities reveals that residential consumers are concerned about environmental and construction quality.

Barriers for transitioning into green buildings were recorded -

MOST POPULAR: **high cost** **25%**

lack of availability **18%**

LEAST POPULAR: **lack of belief in the value of green buildings** **4%**

Most respondents claim to engage in affordable sustainability practices in their daily lives, tending to use energy efficient appliances, opting for low carbon transportation methods, and investing in creating green spaces within and around their homes. A sample consumer survey of 31 households in Lucknow confirm this hypothesis, with residents using improvised passive cooling methods like wet gunny bags, thermocol sheets, and shading techniques to cope with rising indoor temperatures (refer section *5.8 on page 104* for full details).

This indicates that EWS and LIG consumers can be champions for a net zero built environment . The net-zero transition in affordable housing is not only desirable but achievable, provided that systemic gaps at all scales are addressed through coordinated policy, industry, and community action.

> **Linking electricity and water subsidies to green-rated buildings can directly motivate homeowners.**
>
> *Field experts, Indicc Associates*

4.

Instruments of change

4.1 Performance based impact metrics

Green Building Rating Systems predominantly follow an intent-based approach rather than a performance-based approach.

As of March 1, 2024, IGBC's impact measurement shows 13155 projects of 11.51 billion sq.ft. have been registered; there is no data on how much GHG emissions have been avoided, or the amount of energy conserved.

There are multiple solutions aimed at achieving environmental sustainability, or even Net Zero, in India's building and construction sector. This landscape study identifies national missions, energy conservation building codes, thermal comfort design guidelines, and green building rating systems as some of them. However, each pathway comes with their own method of impact measurement. In particular, green building rating systems are seen to have significant contradictions – in the absence of what is defined as "Green" in the building sector, each rating system comes with their own checklist that focuses on an intent- or input-based approach rather than a performance- or output-based one. The checklist is derived on simulated performances of the building, and not on real-world reporting (Centre for Science and Environment, 2012).

Most recommendations also skew heavily towards managing operational emissions, with limited focus on embodied carbon – only 8-9% weightage is given to materials in green building rating systems. Materials achieving high thermal comfort may have high embodied carbon, reducing their overall efficacy in lowering life cycle emissions.

The lack of a unified and standardised metric of outcome measurement, that is predominantly intent focused rather than performance focused, renders it difficult to measure the overall efficacy of existing solutions.

4.1.1. Shifting towards performance based "Net Zero" metric

A conceptual performance-based, standardized "Net Zero" metric framework is presented in *Figure no. 9 on page 63.* The framework presents three key indicators – **emission reduction, natural resources saved, and affordability** as the primary measurement criteria.

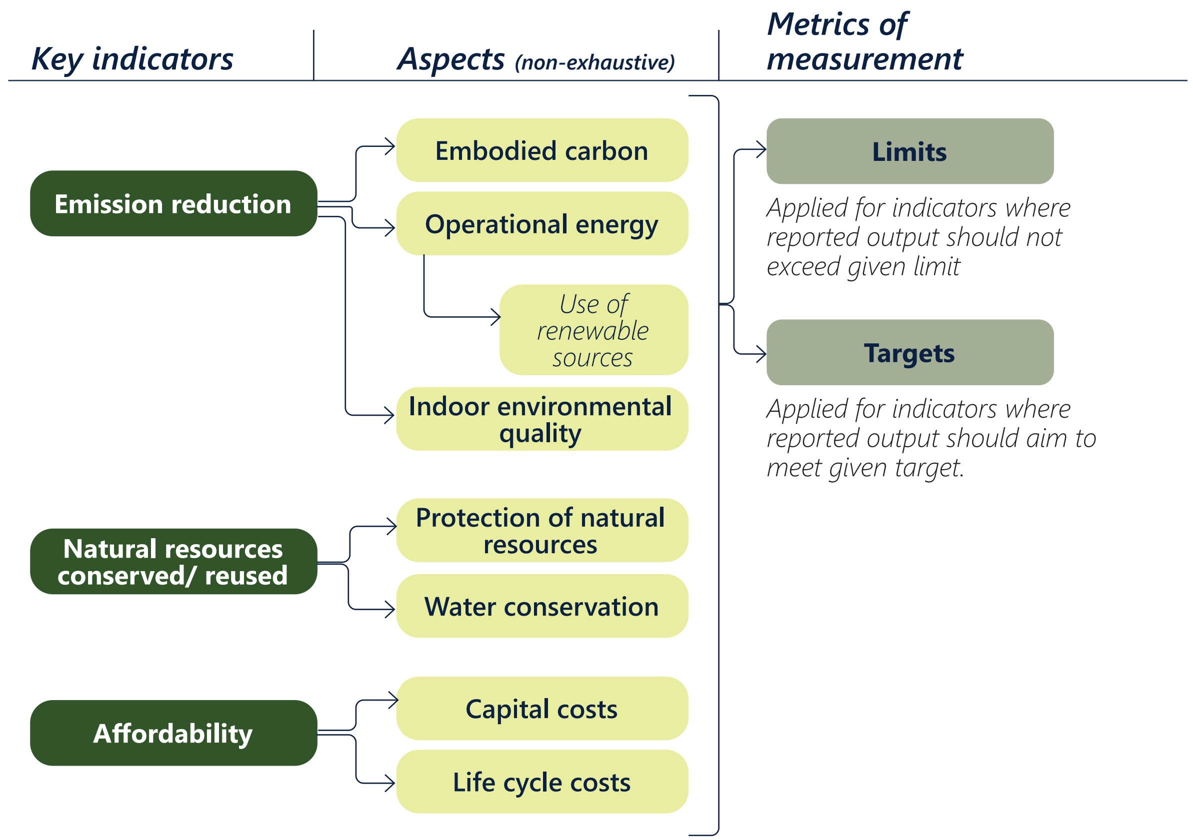


Figure no. 9. Conceptual framework for a performance based "Net Zero" metric system

A limits and targets based impact measurement system should be introduced, with post-occupancy reporting done a minimum of 12 month after completion.

This can be further sub-classified into methods of capturing emissions, i.e. embodied carbon, operational emissions through energy use per unit area from space heating/ cooling and other domestic functions, indoor environmental quality through particulate matter, ventilation rates etc. The metric framework should also capture natural resources saved during the design/ construction phase as well as during operational phase. Ultimately, affordability, measured both through capital construction cost and life cycle cost is imperative to ensure that solutions and pathways are accessible to all income segments.

Two methods of impact measurement are recommended – **setting limits** for indicators where measured output should not cross a certain threshold, such a pre-determined embodied carbon limit, and **setting targets** for indicators where measured output should maximize to achieve a certain benchmark, such as amount of water conserved and reused per year.

The linchpin in this framework is shifting from a intent-based green rating system done pre-construction or immediately post-construction, to a **performance reporting system** started at least 12 months post occupancy, and carried on for a feasible period.

UK's net zero carbon standard is a great example to study unified metric approach (refer Case Study #5 on *page 65*). This method enables setting standard targets for the building sector in terms of emission reduction.

CASE STUDY #5

UK NET ZERO CARBON BUILDINGS STANDARD: A UNIFIED FRAMEWORK FOR EMISSIONS ACCOUNTABILITY

LOCATION

United Kingdom

YEAR

2025

STUDY

This study focuses on the approach of the UK Net Zero Carbon Buildings Standard and how it has established a unified metric system to calculate emissions, including other parameters that influence overall carbon impact.

The UK standard provides a unified, evidence-based framework to define and verify Net Zero Carbon Aligned Buildings. It prioritizes actual post-occupancy performance over predictive models, ensuring greater accuracy and accountability.

The standard addresses both operational energy, measured via Energy Use Intensity (EUI in kWh/m²/year, with a clear pass/fail threshold) and embodied carbon, assessed using the BS EN 15978 standard. All metrics are normalized per Net Internal Area (NIA) for cross-comparability.

It mandates detailed reporting of on-site renewable energy generation and its use versus grid export, and encourages tracking of water use, refrigerant leakage, and thermal loads. This performance-based approach ensures transparent, verifiable progress toward true net zero goals.

Box number. 7. Source: UK Net Zero Carbons buildings standard (pilot version), 2025

4.2 Unlocking decarbonization through regulatory mechanisms

ENS policy is not mandated but notification is initiated in 17 states. RACHNA guidelines for PMAY have seen only 6 pilots till date.

In India's building and construction landscape, there are only two legally binding instruments that regulate the development of urban forms – the **Building Byelaws** and **Development Control Regulations**. Most policies and schemes fail in implementation when they are not connected to these two regulatory instruments.

The implementation mechanisms mapped in *Finding 3 on page 42* and *Finding 4 on page 48* reveal this gap – multiple solutions exists for both pathways, with no communication between parties, and overlapping roles and responsibilities. Energy conservation building codes for residential sector are not legally mandated in most Indian states and cities. The ENS policy has only initiated notification in 17 states. However, this is also not specifically attuned for the affordable housing sector. The applicability of the code rules out independent affordable homes. The limited implementation of RACHNA guidelines in affordable homes built under PMAY further reveals a gap in robust implementation mechanisms of energy efficiency pathways in affordable housing. The gap in implementation mechanisms can be addressed through two regulatory mechanisms –

4

4.2.1. Mandating recommendations through Building Byelaws

Building codes, policies, and schemes are not legally binding. While ENS can be notified state-vide, for implementation the compliance and mandate is integrated into the building permission process through the Building Byelaws (Government of Karnataka, 2018).

This study thus recommends the development of a streamlined process of integrating key clauses of the Eco Niwas Samhita into the Building Byelaws, specifically addressing the low-income housing segment. The latest edition of the Model Building Byelaws gives specific recommendations for Low Income housing in terms of minimum plot area, minimum dimensions for room sizes and layouts, structural requirements, and regulations for land development (Ministry of Housing and Urban Affairs, 2016). However, the chapter on "Green Buildings and Sustainability Provisions", incorporating recommendations from ECBC 2007, do not provide targeted recommendations for the Low Income housing segment. This leads to blanket regulations, rendering all plots up to 100 sqm ineligible for any sustainability provisions, and mandating all plots above 3000 sqm (including mass affordable housing) to comply with all 10 provisions (MoHUA, 2016, pp. 115-120).

In many states, an additional FAR of 5-10% is provided for GRIHA certified residences.

Kerala provides rebates on property tax to IGBC certified buildings.

A specific segment for affordable housing in the"Green Buildings and Sustainability Provisions", tailored to the recommendations and approach discussed in the findings chapter is also required – to mandate net zero pathways in affordable housing.

4.2.2. Incentivising solutions through Development Control Regulations (DCRs)

DCRs are planning regulations that govern the development of a city through zoning regulations, Floor Area Ratios (FAR), height limitations, set-backs, parking requirements, plot sizes etc. In terms of legal mandates, DCRs supersede Building Byelaws, but are typically implemented in tandem with the later by city governments to guide and regulate development, particularly at the neighbourhood level. The provisions in a DCR have been shown to impact housing affordability and influence sustainable development (Niti Aayog, 2021). This study thus recommends the integration of non-fiscal incentives such as free of cost FAR for mass affordable housing projects that integrate net zero measures, or fiscal incentives such as reduced development fees for projects that meet green building criteria. While this is currently practised through a range of instruments in multiple states across India, there is a need to consolidate these incentives under city-specific regulations to ensure successful implementation on ground.

POLICY #3 FOCUS

SUCCESSFUL IMPLEMENTATION OF ECBC FOR COMMERCIAL BUILDINGS IN TELANGANA

STATE

Telangana

PLAN

Telangana State Energy Conservation Building Code (TSECBC)

STUDY

Telangana is a leading Indian state in adopting and implementing the Energy Conservation Building Code (ECBC) for commercial buildings. The state made ECBC compliance mandatory in 2014 through Telangana Municipalities Act, 2019, this was enforcement to all urban local bodies through the online Development Permission Management System (DPMS). No commercial building can now be constructed in Telangana without ECBC compliance certification.

Applicability:

All new commercial and non-residential buildings with a plot area >1000 m^2 or built-up area >2000 m^2.

ECBC Clauses Implemented

The Telangana State ECBC (TSECBC) is based on the national ECBC developed by the Bureau of Energy Efficiency (BEE), Ministry of Power, and includes the following key clauses for commercial buildings: Building Envelope:

Lighting Systems:

HVAC Systems:

Electrical Systems:

IMPACT:

Approximately 430 commercial buildings have received ECBC compliance certification in Telangana, covering a cumulative built-up area of 1.312 million m^2.

Annual Energy Savings: Estimated at 336 million kWh

Box number. 8. Source: TELANGANA STATE ENERGY CONSERVATION BUILDING CODE (ECBC) FOR COMMERCIAL BUILDINGS, 2023

4.3 Procurement reforms for construction materials

While some recommendations exist for “sustainable materials and construction technologies”, implementation of solutions across scale is impacted by the current procurement system, recommending that only materials incorporated in Schedule of Rates be used for public work projects, including affordable housing (refer *Figure no. 8 on page 48*). This implies that most sustainable materials that currently exist in the market are not used in mass affordable housing projects, unless specifically incentivised. In order to ensure a sustained integration of sustainable materials in all affordable housing construction, this instrument recommends the following –

4.3.1. Building a consolidated database of sustainable materials and construction techniques applying a unified measurement metric

Building a consolidated database with a unified measurement metric is the first step towards procurement reform for sustainable materials/ construction technologies. Rawal et al., (2024), and International Finance Corporation, (2017) discuss the development of an embodied energy database for commonly used construction materials using the LCA approach. Such a database provides a clear comparative assessment of all building materials against a unified benchmark. Supplementing this with specific embodied emission reduction targets for the building sector would further strengthen the assessment of building materials/technologies. The consolidated database of materials should also enable the mapping and curation of manufacturers and suppliers that provide detailed technical specifications of the materials to be used in preparation of construction drawings, tendering, and estimation.

4.3.2. Developing a Green Schedule of Rates (SoR) and Analysis of Rates (AoR) for affordable housing

BMTPCs Compedium (2023) lists 69 emerging building technologies with procedure to integrate them to SoRs through PACS but does not discuss sustainability quantiatively. A database as mentioned in this report can be used to identify cost-effective, high impact materials for all infrastructure, especially affordable housing. This study recommends the preparation of a Green Schedule of Rates providing standardised rates of materials, technologies, and construction processes/ services. *Table no. 9 on page 72* gives a sample chart

BMTPC has developed “Compendium of emerging technologies”, listing 69 emerging construction materials and technologies, along with procedures for integrating them into SoR.

LEGEND

worse than base case

better than base case

	Avg cost per sqm. (Rs.)	EEV (MJ/sqm.) *(sourced from secondary sources)*
Walling Material		
Brick Wall (BASE CASE)	1050	3091.5
CSEB (Compressed Stabilized Earth Block)	852.78	803
Fly ash Block	572.92	800
Solid Concrete Block	2187.50	1065
Hollow Concrete Block	1756.95	799
AAC Block	2206.23	1506
Walling Technique		
Structural Stay in Place Formwork	800	N/A
Rat Trap Wall	1150	N/A
Light gauge Steel Frame Structure	5000	N/A
Glass Fiber Reinforced Gypsum panel	1120	N/A
Reinforced EPS Core panel System	2705	N/A

Table no. 9. Comparison chart on cost and embodied energy values of commonly recommended wall materials/ technologies by BMTPC

of commonly recommended walling materials based on approximate market costs.

The Green SoR should further provide the following information to ensure holistic decision-making in selecting green materials/technologies for construction

- **What is the embodied carbon savings of the material?**
- **What is the operational emissions/utility cost savings over the lifetime of the material?**
- **How is its overall performance over life time compared to a conventional material it aims to replace?**

The Green SoR should be supplemented with a detailed Analysis of Rates of items and services, providing a comprehensive cost analysis for each item. This ensures transparency and accuracy in the costing process. The AoR should further provide a rate comparison between sustainable and conventional materials, to enable data driven decision making in selection of materials. Developing a Green SoR that serves as a standardised rate document ensures all public works projects including affordable housing are built using sustainable materials and technologies.

4.4 Mandatory standards for "Net Zero" built environment

Successful implementation of policies is contingent to tactical support for implementing actors. Regulatory reforms guide the zoning and general building standards. The actual design for net-zero integration in housing and neighbourhood infrastructure should be standardised through design, implementation and maintenance standards. There exist some design standards, such as RACHNA guidelines on thermal comfort, and the ENS code. These are also restricted to thermal comfort and energy efficiency.

While there are no national best practices, the Greater Manchester Combined Authority (GMCA) poses as one — having developed a set of 3 documents to achieve net zero ambitions and outcomes set in GMCA policy (details outlined in *case study on page 75*). A comprehensive set of standards and SoPs are needed that enables net-zero implementation across all building and neighbourhood level infra. Details of these are -

4.4.1. Design guidelines

ENS and RACHNA guidelines give minimum baselines for building envelope U values, RETV and SRI but they fail to include design specifications on construction techniques such as rat trap bond, filler slabs etc. There is also limited focus on indoor thermal comfort and air quality, incorporating insulation thicknesses and quality

CASE STUDY #8

DESIGN GUIDANCE FOR NET ZERO BY GREATER MANCHESTER COMBINED AUTHORITY

LOCATION

Manchester, United Kingdom

TYPE

Guideline document

STUDY

This study is a review of design and implementation guidelines which specifically focuses on how to design buildings to achieve the net zero ambitions following a GMCA policy.

OBSERVATIONS:

The guidelines are spilit into 3 documents - Design guidance for Net Zero, Low carbon heat and Submission guidance

The first document sets out net-zero taxonomy, key principles and design of buildings.

The second part specifically focuses on operational energy and low carbon heating systems at an individual as well as neighbourhood scale.

'Submission guidance' focuses on what to submit as part of a planning application to cover the energy and carbon statement element of a submission.

Although each of them can be read independently from the other documents, the reader may find it useful to refer to all three parts as they provide comprehensive guidance on net zero implementation.

Box number. 9. Source: Net Zero guidance – A suite of three guides, March 2025

ENS and RACHNA guidelines give minimum baselines for building envelope U values, RETV and SRI. But they fail to include design specifications on construction techniques such as rat trap bond, filler slabs etc.

standards for building envelopes in different climatic zones.

A design guideline provides unit, block, and site level spatial standards on the practical application of net zero policies. This includes the usage specifications of passive design techniques, alternate materials and construction techniques pertaining to thermal comfort. A comprehensive design guideline should also account for housing affordability through the choice of materials, construction techniques, and design recommendations.

4.4.2. Implementation manuals

An implementation manual provides support to the design guideline by detailing out procurement changes in the form of contractor agreements/guidelines for contractor selection pertaining to thermal comfort design implementation. It also provides material specifications, templates of standard Good for Construction (GFC) drawings, Bill of Quantities (BoQ) and other relevant tender documents. A comprehensive implementation manual also incorporates project monitoring tools such as Job Aids including site visit checklists, documentation methodology, survey methodology to ensure standardization in measuring policy compliance on ground.

4.4.3. Maintenance manuals

A study on rooftop solar panels in composite zones in India (Yadav *et al.*, 2022) found that soiling can affect their efficiency by upto 0.39% per day, highlighting the significance of maintenance in active systems. Similarly, simple maintenance schedules and procedures can prevent degradation of the installed solutions and direct incentivise adoption of net zero solutions in affordable housing.

Ultimately, the greenest building is one that already exists. Retrofitting a building can result in 50-75% less carbon during construction than constructing the same building from scratch (RMI, 2023). **While building retrofits need deeper research, a maintenance manual helps ensure that buildings stay healthy and efficient throughout their average 50 year lifespan, and possibly beyond.**

This document provides a step-by-step detail on maintenance of all components of the affordable housing unit and community facility, for developers/ contractors responsible for maintenance, and for housing occupants. This also includes specific maintenance for special materials and equipment, along with the frequency of maintenance.

The greenest building is one that already exists.

A maintenance manual can ensure reduction in embodied energy through increasing a building's lifespan.

4.5 Looking beyond the building scale – a case for Low Carbon Neighbourhoods

CURRENT DESIGN PRACTICES ARE A MAJOR IMPEDIMENT TO NET ZERO TRANSITION

Emissions in the built environment come from multiple sources that extend beyond the building. *Table no. 10 on page 80* maps the various operational and embodied emissions of a typical community scale. While construction happens on-site, building materials such as cement, sand, gravel etc. are sourced from the quarries, processed in factories, transported via roads and eventually disposed in land fills or recycling facilities. All of these activities and emissions are outside the boundary of the plot. Similarly, everyday consumption such as the fuel used for cooking, electricity supplied for our heating and cooling needs and water used for drinking and sanitation have a huge network of municipal infrastructure linked to them. Yet, regulatory frameworks such as the state/ city building bye laws, energy codes such as ECBC, and even rating systems such as IGBC-NEST, GRIHA etc. are entirely focussed on the building scale.

The bye laws regulate building density, setbacks and ground coverage on site while ECBC recommends building performance parameters such as envelope design, materials etc. On the other hand, planning at the city level is done through masterplans and zoning regulations, typically revised every 20 year. They fail to keep pace with the India's net zero committments for 2030 as well as advancements in current best practices. A case example of Bengaluru regulatory practices on *page 79* clearly substantiates this issue.

THE MISSING MIDDLE

But, a building is not an isolated entity. It is a part of a larger ecosystem that consumes and emits and interacts with its environment. A case study on split ACs on *page 82* unfolds this interconnected relationship. A neighbourhood scale approach to planning acts as a perfect balance between siloed buiding scale and the convoluted city scale.

Regulatory frameworks such as the bye laws, energy codes such as ECBC, and even rating systems by IGBC, TERI etc. are entirely focused on the building scale.

4

CASE STUDY #6

BENGALURU BUILDING REGULATIONS - IMPLEMENTATION BARRIERS

LOCATION

Bengaluru, India

STUDY

This study aims to identify the discrepencies in building and energy codes that impeded a consumer/ developer of affordable housing in adopting net-zero mandates and recommendations.

OBSERVATIONS:

The latest version of ECBC was released in 2024, but Karnataka (like most states) has notified ECBC 2017 only. ENS which was first released in 2018 and has since had multiple updates is still not mandated.

The TOD (transit oriendted development) policy that allows for a greater FAR along transit corridors has been approved as of Nov, 2022 but hasn't come into effect. Neither the City municipal bye laws nor the masterplan accommodates it. Though RMP 2031 draft was prepared and includes TOD zones, it is yet to be legally enforced in 2025.

In the building permit process, the NOCs (no objection certificates) from the concerned departments have to be issued within 30 days, failing which the NOCs would be deemed to have been issued despite violating environment clearances.

Box number. 10. Source: BBMP bye laws 2017, 2022 ; Bengaluru RMP 2015

GHG Emissions at Neighbourhood level

	Scope 1	*Scope 2*	*Scope 3*
Built Form	*On site fuel burning*	*Electricity*	*Materials are manufactured off site*
	On site fuel burning	*Electricity*	*Materials are manufactured off site*
Mobility Infrastructure		*Street lighting*	*Infrastructure materials*
	Low or no emissions from use		*Construction of the Lanes*
			Pavers or concrete
		Street lighting	*Embodied emissions in paving materials*
		Street lighting	*Materials*
		fuel burned within boundary due to movement	*Manufacturing of transport vehicles*
		fuel burned within boundary due to movement	*Manufacturing of transport vehicles*
			Manufacturing of bicycle (minimal)
Services	*On site Fuel Burning*	*Electricity for pumping*	*Manufacturing of Pipes, tanks*
	Diesel operations	*Electricity based operation*	*Underground pipes and tanks*
		Water use & pumps	*Plumbing infrastructure*
		Grid Electricity	*Lighting infrastructure*
			Equipment and collection vehicles
Open Spaces		*Grid electricity*	*Construction of Pathways etc.*
		Grid electricity	
		Electricity for lights/ fountains	*Paving materials*
		minor lighting	*Concrete/metal/wood structures*

Legend

- Individual
- Shared
- GHG Emissions
- Low Impact EE
- High Impact EE
- Low Impact OE
- High Impact OE

Table no. 10. Emissions in a neighbourhood

Sector and Elements	**Embodied Energy**	**Operational Energy**
Housing typologies	Construction materials (cement, steel, bricks)	Energy use for lighting, HVAC, water, appliances.
Community centres/halls	Structural materials, finishes	Lighting, AC, events.
Roads and streets	Materials use (bitumen, concrete)	Negligible except for lighting.
Bicycle lanes	Constructed from asphalt/ concrete;	Minimal operational impact
Pedestrian footpaths	Pavers or concrete.	
Parking areas	Hard paved surfaces	
Transit access points	Platforms, shelters	
Public Transport (Bus, Auto etc)	Manufacturing of the transport	Fuel usage
Private Transport Motorised (Cars,scooters)	Manufacturing of the transport	Fuel usage
Private Transport Non-Motorised (Bi-Cycle)		No Fuel usage
Water supply systems	Pipes, tanks.	Pumps, treatment energy
Sewerage & drainage	Construction of underground systems	Pumping and treatment if mechanized.
Sanitation facilities at neighbourhood scale	Materials (tiles, fixtures)	Water use, flushing systems.
Electricity & street lighting	Poles, wiring, fixtures	Daily electricity usage
Solid waste management facilities	Construction of bins, sheds	Operations like collection, composting.
Parks and playgrounds	Constructed play structures, pathways, landscaping materials.	Lighting
Community gardens	Minimal built input (soil, fencing).	Lighting
Green buffers/tree plantations	Limited EE in planting.	Low impact OE
Plazas, open courtyards	Paving, hardscaping.	Lighting or water features
Public seating/shaded structures	Built Form Permanent structures using materials like steel, RCC, wood.	

CASE STUDY #7

THE IMPACT OF HEAT REJECTION FROM SPLIT AIR CONDITIONER ON OUTDOOR AIR TEMPERATURE IN HIGH-DENSITY RESIDENTIAL AREAS

LOCATION

Pearl River Delta, China

TYPOLOGY

High Rise Building

STUDY

This study aims to develop an outdoor temperature model that accounts for the impact of air conditioner heat rejection.

OBSERVATIONS:

Split AC waste heat increased outdoor air temperatures by +2.2 °C compared to conditions without such heat rejection.

Even a moderate +2 °C exterior temperature increase can reduce AC efficiency, resulting in 3.1% more cooling energy demand and 7.3% more electricity consumption.

AC waste heat is the predominant source of anthropogenic heat in such neighborhoods—a much larger factor than vehicular traffic.

Halving district vegetation increased UHI impacts by +3.2%, while doubling vegetation reduced them by −3%, highlighting the moderating effect of green cover.

High-density residential areas can significantly restrict ventilation, leading to the accumulation of heat from split air conditioners within these spaces, which severely impacts the outdoor thermal environment.

Box number. 11. Source: Modeling the impact of heat rejection from split air conditioner on outdoor air temperature in high-density residential areas, 2025

4.5.1. Neighbourhood scale decarbonization strategies amplify the building level strategies, and reduce external stress on building

To shift the narrative of “green buildings” as parts of an ecosystem that offers adequate shelter with basic services, infrastructure, livelihood opportunities along with environmental and socio-economic safety including disaster-resilience (definition from National Mission on Sustainable Habitat) and draft recommendations that amplify building-level strategies. For instance, Barcelona’s superblocks policy restricts vehicular movement to 1 out of 3 streets, promoting low-carbon neighbourhoods in high-density cities. Solar Rights thinks beyond the plot; protects RTS users from new construction that can block their sunlight access and hence multiplies returns on the technology (ref. *page 50*).

Community-based solutions and shared resources reduce stress on building to be a self sufficient unit. A study by CRRI (Advani, Mukti & Sharma, Niraj. 2021) found 14% reduction in fuel consumption, and 15% reduction in CO_2e by shifting to non-motorised transportation on short trips. As seen in *Table no. 8 on page 52,* community solar solutions can multiply solar potential that is limited by contesting terrace space and rights.

14% reduction in fuel consumption, along with 15% reduction in COe by shifting to non-motorised transportation in short trips

CRRI, Indian Highways, 2021

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Source: Unsplash

5.

Annexure.

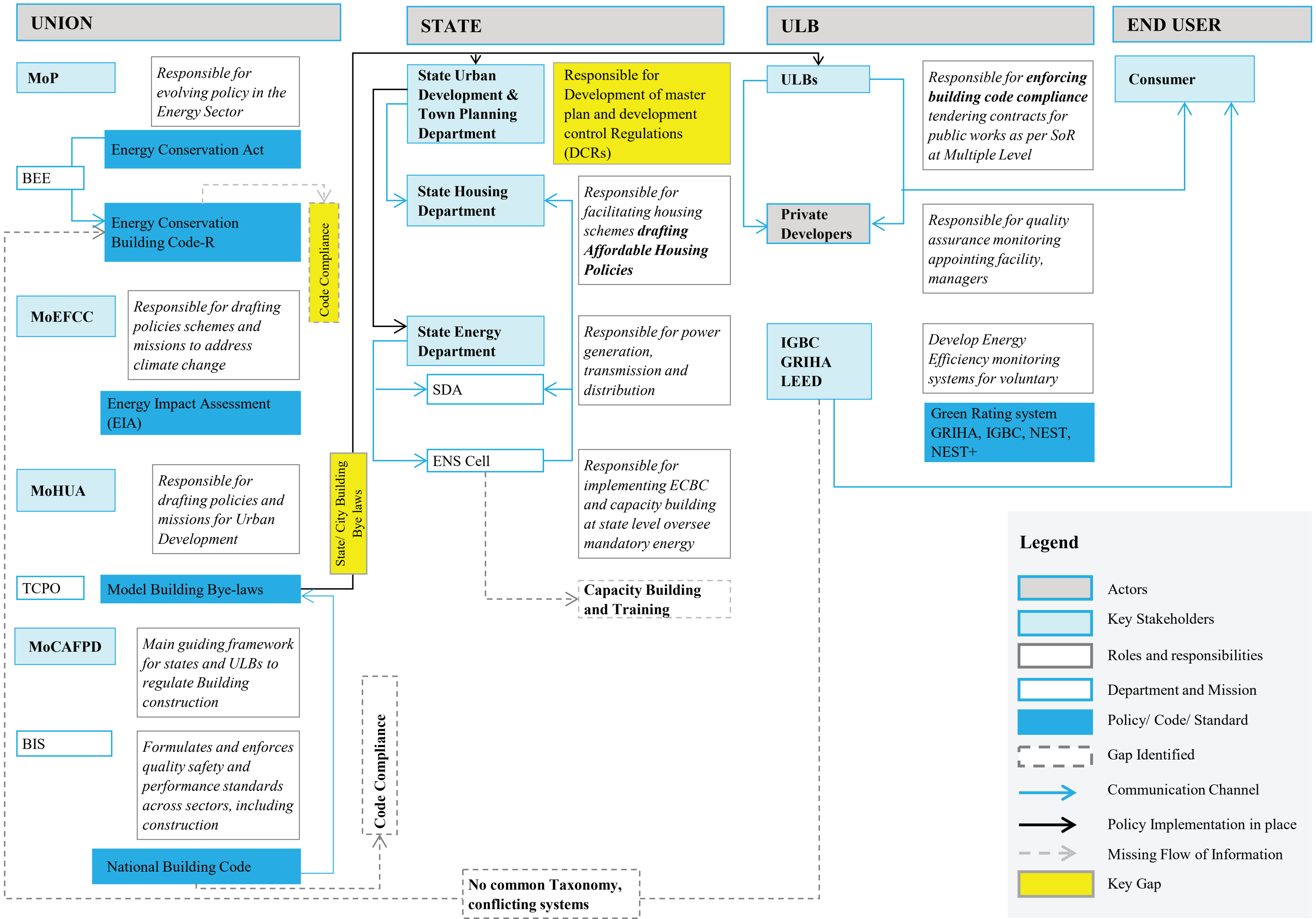
5.1 Literature reviewed

Table no. 11. List of literature reviewed

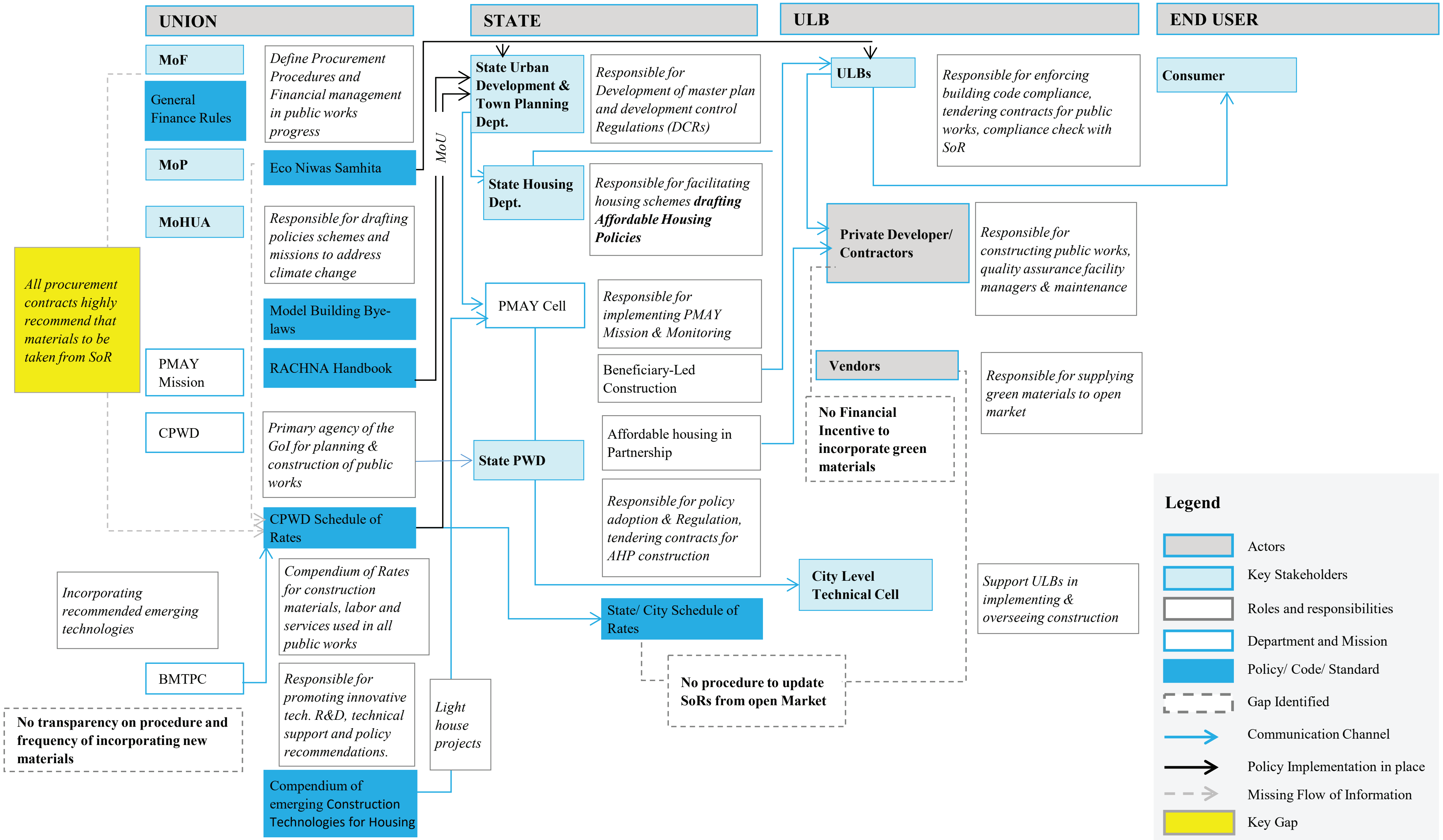
Instrument category	Description of the instrument	Policy titles	Description of documents	Target sector
National net-zero targets	National level climate targets and strategies	Fourth Annual Communication and Initial Adaptation Communication, 2024 National Mission for Sustainable Habitat (NMSH) India Cooling Action Plan	National level mission on promoting low-carbon urban growth, achieving India's NDCs through built environment interventions, and building resilient cities. National level cooling action plan identifying strategies and cooling pathways for key sectors including built environment.	\ Net zero pathways
Regulatory instruments	Legal tools/ regulatory frameworks that guide built environment development	Energy Conservation Act Model Building Bye Laws 2016 Development Control Regulations (state wise) Delhi Schedule of Rates 2021	A law that aims to reduce energy intensity of the Indian economy. A model regulatory framework regulating coverage, height, building bulk, and architectural design and construction aspects of buildings, to ensure orderly urban development. Serve as statutory policy instruments that guide and regulate land use, building form, and infrastructure provision to ensure context-specific urban development. Standardized rate document for materials, construction technologies prepared for all public works projects.	\ Built environment \ Net zero pathways
Building codes	National instruments for regulating building design and construction across the countryW	National Building Code 2016 Energy Conservation and Sustainable Building Code (ECBC) 2024 Eco Niwas Samhita (ENS) 2024	National instrument regulating building construction activities across the country. Forms the basis of Building Bye Laws for states. National level energy-conservation building code for commercial buildings. National level energy-conservation building code for residential buildings.	\ Built environment \ Net zero pathways
Polcies & schemes	Guidelines on policy/ scheme overview, focus, implementation, and impact	Pradhan Mantri Awas Yojana State Affordable Housing schemes		\ Affordable Housing
Policy support	Design guidelines and compendiums supporting policies	Innovative Construction Technologies & Thermal Comfort in Affordable Housing (RACHNA) Handbook BMTPC Compendium of Emerging Construction Technologies for Housing & Infrastructure	Thermal comfort design guidelines for affordable housing construction. List of 69 emerging materials and construction technologies	\ Built environment \ Affordable Housing
Green building rating system	Rating and certification systems for greening of projects in the built environment	IGBC NEST and NEST Plus GRIHA framework Green Pro Ecolabeling	Green building rating systems for affordable housing. Ecolabel certification and directory of 9500 green materials	\ Affordable Housing \ Net zero pathways

5

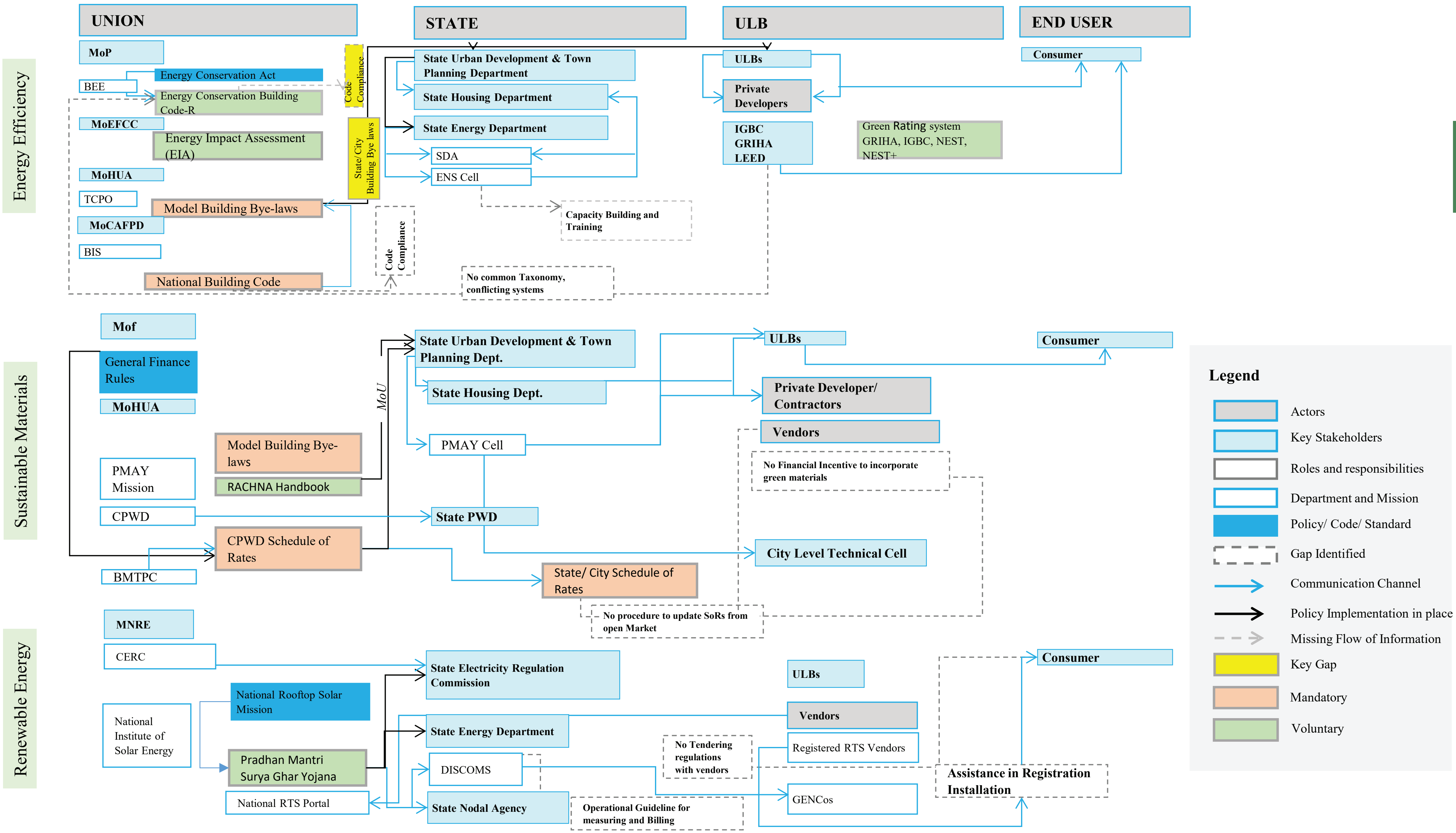
5.2 Implementation mechanism - energy efficiency



5.3 Implementation mechanism - sustainable materials and techniques



5.4 Combined implementation mechanisms for all Net Zero pathways



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5.5 Cost vs quality - sustainable materials and techniques

CODES -> BENCHMARKS	ECBC	Eco Niwas Samhita	RACHNA guideline	IGBC NEST/ NEST plus
U value (wall/ roof) in W/m2	0.44 W/m2K	≤ 1.2 W/m2	-	Composite, Hot-Dry: ≤ 1.8 WarmHumid: ≤ 2.0
RETV (wall)	(U value 0.26 W/m2K)	≤ 15 W/m2	≤ 15 W/m2	(U value ≤ 1.5)
Solar Reflectance Index SRI (roof)	>0.6	>0.6	- (high SRI)	>0.78

Table no. 12. Comparison of benchmarks for energy efficiency

Building Material	Avg. cost per sqm. (Rs.)	Embodied Energy Value (MJ/sqm.)	U-Value (W/m2.K)	RETV (W/ meter sq.)	SRI (0-1)
Walling Material					
Brick Wall	1050	3091.5	2.41	16.62	
CSEB (Compressed Stabilized Earth Block)	852.78	803	2.79	14.35	
Fly ash Block	572.92	800	0.35	16.34	
Solid Concrete Block	2187.50	1065	2.00	25.48	
Hollow Concrete Block	1756.95	799	0.73	N/A	
AAC Block	2206.23	1506	0.78	12.35	
Walling Technique					
Structural Stay in Place Formwork	800	N/A	0.44	N/A	
Rat Trap Wall	1150	N/A	2.11	N/A	
Light gauge Steel Frame Structure	5000	N/A	1.37	N/A	

Building Material	Avg. cost per sqm. (Rs.)	Embodied Energy Value (MJ/sqm.)	U-Value (W/m2.K)	RETV (W/ meter sq.)	SRI (0-1)
Glass Fiber Reinforced Gypsum panel	1120	N/A	2.06	N/A	
Reinforced EPS Core panel System	2705	N/A	0.56	N/A	
Roofing Material					
RCC	2500.00	785.35	1.58		0.41
Cool Roof Paint	205.00	803.06	1.58		1.00
RCC with Reflective tiles	3671.47	811.53	1.58		0.90
Roofing Technique					
RCC filler slab	2152.78	346.48	1.2		0.41

Table no. 13. Cost and quality comparison of wall and roof materials

meets ENS benchmark

does not meet ENS benchmark

5

5.6 Incentives provided for green building ratings

State	Additional Incentives	Department
Haryana	IGBC: Additional FAR of 9% (Silver), 12% (Gold), 15% (Platinum)	Town & Country Planning
Jharkhand	IGBC: Additional FAR of 3% (Silver), 5% (Gold), 7% (Platinum)	Urban Development & Housing Department
Kerala	Upto 10% A reduction of 50% in one time building tax	Local Self Government Development
Punjab	IGBC: 100% scrutiny fee waiver; GRIHA/BEE: 5% additional FAR	Dept. of Local Govt / Housing & Urban Development
Rajasthan	IGBC: Up to 0.15% additional FAR; MSMEs: 50% subsidy (up to ₹50L) on green measures	Urban Development Department
Uttar Pradesh	Upto 5% additional FAR	Housing and Urban Planning Department
West Bengal	Upto 10% additional FAR	Department of Municipal Affairs
Gujarat	IGBC: Additional FAR of 9% (Silver), 12% (Gold), 15% (Platinum)	Town & Country Planning
Andhra Pradesh	IGBC: Additional FAR of 3% (Silver), 5% (Gold), 7% (Platinum)	Urban Development & Housing Department
Maharashtra	IGBC: 3%-7% additional FAR (Silver to Platinum)	Department of Urban Development, Government of Maharashtra

Table no. 14. State-wise comparison of green building certification incentives for developers

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5

5.7 Sample consumer survey

The next phase of research focuses on Focus Group Discussions (FGDs) and targeted household surveys, conducted across a set of diverse geographies and housing typologies. States will be selected to reflect a mix of climatic zones, construction technologies, and regulatory environments.

SURVEY FRAMEWORK	Household Characteristic	Awareness on Net Zero Affordable housing	Understanding Thermal comfort & Passive Design	Affordability & Financial Aspects
OBJECTIVES	Understand the respondent's background, socio-economic status, and earning capacity to assess how these factors influence housing and energy-efficiency choices.	Evaluate current housing conditions, satisfaction levels, and identify areas needing improvement, especially related to size, ventilation, and thermal comfort.	Assess the thermal comfort levels of respondents' homes, their cooling habits, and familiarity with passive design techniques to gauge interest in non-mechanical cooling solutions.	Determine consumers' willingness to pay for energy-efficient homes and the impact of financial incentives on decision-making.
	Demographics	Knowledge Level on Energy-efficient Homes	Awareness on Passive design and Thermal Comfort	Willingness to Pay More for Long-term Energy Savings
	Dwelling Characteristics	Factors Influencing Interest in Energy-efficient Homes	Thermal Discomfort issues faced	Influence of Financial Incentives on Home Selection
	Economic status Annual income	Challenges to Owning Net Zero Housing	Current passive features at home	Importance of Affordability in Home Selection
	Housing and Living Conditions House characteristics		Willingness to- • Upgrade Home with Passive Features • Pay More for Passive Design Features	Government Subsidy for Home Purchase
OUTCOMES	- Socio-economic segmentation (income level, job type) - Gender and household size trends	- Percentage of respondents living in poorly ventilated or overcrowded homes - Awareness level of Net Zero or energy-efficient housing	- Seasonal discomfort trends (e.g., summer overheating) - Reliance on mechanical cooling vs. passive strategies	- Suggestions for improving affordability through policy or incentives - Willingness to pay more for energy-efficient features

Figure no. 10. Consumer affordability of PMSGY

5.8 Findings from preliminary household survey

Respondent ID	Age Group	Family Size	Occupation	Housing Category	Income Bracket (Lakhs)	Typology	Built Up Area	Tenure (Years)	Satisfied with Home Size	Heard of NZBE	Thermal comfort Home	Willingness to Pay More
R001	18-40	1-2	Salaried	EWS	<1 Lakh	1 BHK	<30	1-3	Yes	No	Somewhat Comfortable	Nothing
R002	18-40	1-2	Blue-collar	EWS	1-3	1 BHK	<30	1-3	No	Not Sure	Uncomfortable	10-20%
R003	18-40	5+	Blue-collar	LIG	1-3	2 BHK	30-60	1-3	Yes	Yes	Uncomfortable	Nothing
R004	18-40	1-2	Blue-collar	LIG	<1 Lakh	2 BHK	30-60	1-3	No	No	Uncomfortable	Nothing
R005	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	Yes	Not Sure	Uncomfortable	Nothing
R006	18-40	1-2	Blue-collar	LIG	1-3	2 BHK	30-60	1-3	Yes	No	Uncomfortable	10-20%
R007	18-40	1-2	Blue-collar	EWS	1-3	1 BHK	<30	1-3	No	No	Uncomfortable	Nothing
R008	18-40	1-2	Blue-collar	EWS	<1 Lakh	1 BHK	<30	1-3	No	No	Uncomfortable	Nothing
R009	18-40	1-2	Blue-collar	LIG	1-3	2 BHK	30-60	1-3	Yes	No	Uncomfortable	Nothing
R010	18-40	1-2	Blue-collar	EWS	1-3	1 BHK	<30	<1	No	No	Uncomfortable	Nothing
R011	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	No	Not Sure	Somewhat Comfortable	Nothing
R012	18-40	1-2	Blue-collar	EWS	<1 Lakh	1 BHK	<30	1-3	Yes	No	Somewhat Comfortable	Nothing
R013	18-40	1-2	Salaried	EWS	1-3	1 BHK	<30	<1	Yes	Not Sure	Uncomfortable	Nothing
R014	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	No	No	Somewhat Comfortable	10-20%
R015	18-40	1-2	Salaried	EWS	1-3	1 BHK	<30	<1	Yes	No	Uncomfortable	Nothing
R016	18-40	1-2	Blue-collar	LIG	<1 Lakh	2 BHK	30-60	<1	Yes	Not Sure	Uncomfortable	10-20%
R017	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	No	Yes	Very Uncomfortable	Nothing
R018	18-40	1-2	Blue-collar	EWS	1-3	1 BHK	<30	1-3	No	No	Uncomfortable	Nothing
R019	18-40	1-2	Blue-collar	LIG	1-3	2 BHK	30-60	1-3	Yes	Yes	Somewhat Comfortable	10-20%
R020	18-40	1-2	Salaried	EWS	1-3	1 BHK	<30	1-3	Yes	No	Very Uncomfortable	10-20%

Respondent ID	Age Group	Family Size	Occupation	Housing Category	Income Bracket (Lakhs)	Typology	Built Up Area	Tenure (Years)	Satisfied with Home Size	Heard of NZBE	Thermal comfort Home	Willingness to Pay More
R021	18-40	1-2	Blue-collar	EWS	<1 Lakh	1 BHK	<30	1-3	No	No	Uncomfortable	Nothing
R022	18-40	1-2	Blue-collar	LIG	1-3	2 BHK	30-60	1-3	Yes	No	Uncomfortable	Nothing
R023	18-40	1-2	Blue-collar	EWS	1-3	1 BHK	<30	<1	No	No	Uncomfortable	Nothing
R024	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	No	Not Sure	Somewhat Comfortable	Nothing
R025	18-40	1-2	Blue-collar	EWS	<1 Lakh	1 BHK	<30	1-3	Yes	No	Somewhat Comfortable	Nothing
R026	18-40	1-2	Salaried	EWS	1-3	1 BHK	<30	<1	Yes	Not Sure	Uncomfortable	Nothing
R027	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	No	No	Somewhat Comfortable	10-20%
R028	18-40	1-2	Salaried	EWS	1-3	1 BHK	<30	<1	Yes	No	Uncomfortable	Nothing
R029	18-40	1-2	Blue-collar	LIG	<1 Lakh	2 BHK	30-60	<1	Yes	Not Sure	Uncomfortable	10-20%
R030	18-40	1-2	Salaried	LIG	1-3	2 BHK	30-60	1-3	No	Yes	Very Uncomfortable	Nothing
R031	18-40	1-2	Blue-collar	EWS	1-3	1 BHK	<30	1-3	No	No	Uncomfortable	Nothing

The preliminary survey of 31 households in Lucknow's affordable housing offers valuable insights into residents' lived experiences, highlighting widespread thermal discomfort, low awareness of Net Zero housing, and the absence of formal passive cooling measures. Many residents depends on resource-constrained adaptations to mitigate indoor heat and improve thermal comfort. These findings reinforce secondary literature insights, underscoring the need for targeted affordable and accessible solutions to drive Net Zero transition.

5.9 GRIHA & IGBC Certification process for Affordable Housing

GRIHA CERTIFICATION

PRECONSTRUCTION

- **Registration of the Project** — Developer registers the project on GRIHA's online portal.
  Fee: Till 10,000 sq.m Builtup area 2,50,000 + GST+ 18% GST
  For every sq.m above 10,000 sq.m INR 2,50,000 + additional built up charged @ INR Rs 3.75/sqm + GST
- **Pre-Assessment Documentation Submission** — Submit design-stage documents for preliminary assessment.
- **Request for design intent evaluation (Optional)** — Separate fee based on built-up area (generally 25–30% of final certification fee) Not Mandatory

POST CONSTRUCTION

- **Final Documentation Submission**
- **Site Visits & Third-Party Evaluation** — Included in certification fee
- **Award of Rating** — Project is awarded 1–5 star rating based on compliance

RE-APPROVAL

- **Re-evaluation Fee** — after 5 years

To get a project GRIHA certified, the total fee for an 8,000 sq.m project is INR 2,50,000 plus GST, while for a 15,000 sq.m project, the total fee is INR 2,68,750 plus GST (calculated as INR 2,50,000 plus INR 18,750 for the additional area).

IGBC GREEN AFFORDABLE HOUSING CERTIFICATION

PRECONSTRUCTION

- **Registration of the Project** — Developer registers on IGBC website.
  IGBC Member- ₹29,500 + 18% GST (non-refundable)
  IGBC Member- ₹35,400 + 18% GST (non-refundable)
- **Documentation Submission** — Submit detailed project information and green features as per IGBC Affordable Housing guidelines
- **Pre-Certification** — For built-up areas up to 10,000 sq.m, the IGBC certification fee ranges from INR 65,000 to 75,000 based on membership status; for 10,001–50,000 sq.m, founding members pay INR 1,25,000 plus INR 3.50 per sq.m over 10,000, annual members pay INR 1,35,000 plus INR 4 per sq.m over 10,000, and non-members pay INR 1,45,000 plus INR 4.50 per sq.m over 10,000; for areas above 50,001 sq.m, the fee is INR 2,75,000–3,25,000, with an additional INR 50,000 charged for each building from the 4th onward if each building is at least 5,001 sq.m

POST CONSTRUCTION

- **Final Submission and Evaluation**
- **Review & Site Visit** — Technical review and third-party site inspection Included in certification fee
- **Award of Rating** — Rating awarded: Certified / Silver / Gold / Platinum.

RE-APPROVAL

- **Re-evaluation** — After 3 years

To get an affordable housing project IGBC certified, a non-member with a 12,000 sq.m project would pay a total fee of INR 2,17,120, which includes a registration fee of INR 35,400, a certification fee of INR 1,54,000, and 18% GST of INR 27,720 on the certification fee.

Figure no. 11. Green building certification process outlines

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5.10 Financial Assessment of Conventional Vs Green buildings

Parameter	Base Case	Green Case (5% cost + FAR incentive)	Remarks
Built-Up Area (sq.m)	2843.3	2985.465	5% extra FAR on 2843.3 sq.m
Built-Up Area (sq.ft)	30,600.66	32,130.69	
Number of Dwelling Units (DUs)	80	85	5 additional units with 5% FAR
Cost per sq.ft	1,582.65	1661.78	5% higher in green buildings (TERI,2025; NIUA,2020)
Total Construction Cost	4,84,30,134.55	5,33,94,223.34	The price for the EWS/LIG for government construction are capped at very less margIn less than 5%
Total Cost of the Housing	5,81,16,161	6,40,73,068	As the land belongs to the government 20-30% additional is charged including the amenities, Infrastructure etc
GRIHA Registration Fee	-	2,95,000	2.5 L + 18% GST
Total Government Subsidy for Buyers	2,00,00,000	2,12,50,000	Subsidy per DU (PMAY-U) Rs.1.5 Lakhs (Central Govt)+ Rs.1 Lakhs (State Govt)
Sale Price per Unit	4,80,000	4,80,000	As per market price in Lucknow
Total amount spend by the developer after subsidy	3,81,16,161.46	4,28,23,068	Selling price of the 80 units in base case and 85 in green case
Total Sales Revenue	3,84,00,000 (80 units)	4,08,00,000 (85 units)	Slightly higher due to more units
Net Developer Margin	28,38,38	-20,23,068	The developer's profit of ₹28.38 lakh in the base case turns into a loss of ₹20.23 Lakhs in the green case

Table no. 15. Affordability of a conventional vs green building construction

As affordable housing expands under PMAY-U, integrating green features has become essential—but financially challenging. This analysis compares a conventional project with a GRIHA-certified green alternative, revealing that while the green case benefits from 5% additional FAR and slightly higher subsidies due to the added units, these gains do not offset the increased construction costs and certification fees. Construction costs are approximately 5% higher (NIUA, 2020), and a GRIHA certification fee of ₹2.95 lakh is incurred. With unit prices capped at ₹4.8 lakh, the developer's profit of ₹28.38 lakh in the base case turns into a loss of ₹20.23 lakhs in the green case.

5.11 Stakeholder meetings - field experts

Organisation	Focus of Discussion	Key Takeaways
IEEFA	Renewable Energy	Marketability, end-user costs, and ease of incentives play key roles
CSTEP	Dynamic Model to assess Embodied and Operational Energy	CSTEP enables cross-sector policy simulation at Union, State, and City levels. Uses dynamic systems to assess energy, emissions, and resource use
CEPT University / Carbse	Rating systems and challenges in Affordable housing sector in adopting Net Zero Strategies	Green codes face implementation and conceptual gaps.
JMK Research	Solar PV policy, RE incentives	Highlighted long payback periods, low returns for rooftop solar in Affordable Housing
Mahila Houisng Trust	Energy efficiency, solar rooftop	Highlighted policy-implementation mismatch in rooftop solar for low-load AH consumers.
C40 Cities	Decarbonization strategies for the Cities of Maharashtra by Implementing ECBC	Focused on city-level decarbonization through ECBC, green roofs, water conservation, and RE. Identified gaps in green material procurement/testing and lack of code enforcement.
Indicc Associates	Climate finance in built environment, green standards, coordination gaps, equity-based housing challenges	Highlighted fragmented green definitions, need for national taxonomy, and challenges in coordinating multi-stakeholder affordable housing projects. Emphasized performance resilience, consumer incentives, and integrated sustainability standards.

Organisation	Focus of Discussion	Key Takeaways
Prayas Energy Group	Feasibility of green material use, code implementation challenges, ULB capacity	Identified lack of standardized codes, inadequate ULB capacity
CKinetics	Building energy data, incentive structures, embodied energy policy gaps, regulatory processes	Emphasized lack of energy performance data, need for post-occupancy evaluation, absence of incentives for both users and developers, and weak enforcement of EE policies. Advocated for policy-market balance to drive demand and regulate supply.
IGBC, Indian Green Building Council	Eco labelling, NEST certification	Process of NEST certification and parameters.
Xynteo	Green buildings and ratings	
Transitions Research		

Jana Urban Space Foundation

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