TOWARDS NET ZERO: DECARBONIZING COMMERCIAL BUILDINGS IN GUJARAT

A SCALABLE FRAMEWORK TO SUPPORT INDIA'S 2070 CARBON NEUTRALITY MISSION

SEPTEMBER 2025

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Danish Industry

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CII
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Towards Net Zero: Decarbonizing Commercial Buildings in Gujarat, A Scalable Framework to Support India's 2070 Carbon Neutrality Mission is published by CII's Indian Green Building Council (IGBC) and Confederation of Danish Industry (DI).

This publication is an effort to showcase the insights and outcomes from the project, with the aim of accelerating decarbonization in the built environment. The initiative seeks to support India's climate goals by promoting energy efficiency, adoption of low-carbon materials, and operational performance improvements in commercial workspaces. Through data-driven analysis, policy alignment, and stakeholder engagement, the project aspires to enable a scalable and practical pathway towards carbon neutrality in the building sector, while enhancing occupant well-being, environmental stewardship, and long-term resilience.

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“Net zero is not just a climate target—it is a blueprint for better living. By rethinking how we design, build, and use materials, this report advances the global quest for sustainable cities, responsible consumption, and a healthier, more inclusive future.”

This year marks another milestone in the longstanding friendship between Denmark and India, a partnership built on shared values and commitment to sustainability and green transition. Since the launch of the Indo-Danish Green Strategic Partnership in 2020, collaboration has deepened, bringing forward practical solutions to climate challenges.

This report highlights a critical area where Indo-Danish cooperation can deliver real impact. With India aiming for carbon neutrality by 2070, and Gujarat emerging as a leader in sustainable growth, decarbonizing the building sector is both a challenge and an opportunity. The insights, case studies, and recommendations presented here provide a framework for Gujarat and a replicable pathway for other states in India and beyond.

On behalf of the Ministry of Foreign Affairs of Denmark, including the Danish International Development Agency (DANIDA), I am pleased we can support this important project. Denmark remains committed to working with India to advance our shared vision of a greener, cleaner, and more prosperous world.

H.E. Rasmus Abildgaard Kristensen,
Danish Ambassador to India

India's urban growth presents both a challenge and an opportunity in the context of climate action. Buildings, as the most visible and resource-intensive components of our cities, hold tremendous potential to reduce emissions while enhancing long-term resilience and efficiency.

This report offers a focused, data-driven approach to decarbonizing commercial workspaces—among the highest contributors to building-sector emissions—outlining practical strategies to address both embodied and operational carbon. Its strength lies in its real-world grounding, with solutions that are both actionable and scalable.

The collaboration between Danish Industry, CII, IGBC, and technical experts has resulted in a replicable framework for climate-responsive urban development. We encourage all stakeholders to embrace these insights in shaping future planning and building practices. The government remains committed to supporting such efforts to ensure their widespread adoption and meaningful impact on the country's sustainable growth trajectory.

Shri M. Thennarasan (IAS)
Principal Secretary (Urban Development & Urban Housing Department)
Government of Gujarat

Gujarat, as one of India's most vibrant states, has consistently led the way in sustainable development. As India moves towards its 2070 net zero goal—and with Ahmedabad being India's official contender to host the 2036 Olympics—the need for climate-responsive sports, hospitality, and urban infrastructure has never been more urgent.

This report offers a practical, evidence-based framework for reducing carbon emissions in commercial workspaces through real-world case studies and globally aligned strategies. It demonstrates that environmental responsibility can go hand in hand with operational efficiency, economic viability, and policy relevance.

We commend the collaboration between DI, CII-IGBC, and the project partners for creating a replicable model of climate action. These learnings will inform future policies, empower professionals, and shape the development of net zero infrastructure across sectors. We look forward to actively supporting the broad and impactful rollout of such initiatives through strong government collaboration.

Shri Ashwini Kumar (IAS)
Principal Secretary (Sports, Youth and Cultural Activities Department)
Government of Gujarat

India’s commitment to achieving carbon neutrality by 2070 calls for decisive action across all sectors—and the building industry, which contributes significantly to national emissions, presents a critical opportunity to lead India’s transition to a low-carbon future.

This study represents an important step in turning climate ambition into practical action, outlining a replicable, data-driven pathway for reducing both embodied and operational carbon in commercial buildings. Through life cycle assessments, energy modelling, and implementable measures, it delivers insights that are both rigorous and actionable. It shows that net zero is not an abstract target but a realistic goal—achievable through responsible design, material choices, and performance-led retrofits.

We applaud the collaboration between the Confederation of Danish Industry (DI), Confederation of Indian Industry (CII), IGBC, and the participating workplaces and experts. We urge all stakeholders to adopt these insights and advance our shared goal of a sustainable built environment.

Jayesh Hariyani
Chairman, IGBC Ahmedabad Chapter

Sameer Sinha
Immediate Past Chairman, IGBC Ahmedabad Chapter

The joint initiative of CII and DI has been instrumental in empowering the building industry particularly in Gujarat to embrace green practices and unlock the intangible benefits of sustainable design. Building on this foundation, the collaboration has expanded its focus to explore pathways for achieving Net Zero Energy and Carbon status across both greenfield and brownfield projects. The carefully selected case studies stand as inspiring examples, demonstrating the potential for exemplary Net Zero performance in the years ahead.

I am confident that the study's recommendations will serve as a valuable resource for the Government in shaping policies and setting ambitious Net Zero Energy and Carbon goals.

Mr K S Venkatagiri
Executive Director, CII GBC

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ACRONYMS

AAC – Autoclaved Aerated Concrete
AHU – Air Handling Unit
ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers
BOQ / BOM – Bill of Quantities / Bill of Materials
BEE – Bureau of Energy Efficiency
B6 – Operational Energy Phase (in LCA context)
CII – Confederation of Indian Industry
CAV – Constant Air Volume
COP – Coefficient of Performance
COP26 – 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC)
CVRMSE – Coefficient of Variation of Root Mean Squared Error
DANIDA – Danish International Development Agency
DI – Confederation of Danish Industry
DGU – Double Glazed Unit
DTDA – Danish Trade Union Development Agency
ECBC – Energy Conservation Building Code
ECM – Energy Conservation Measure
EPD – Equipment Power Density
ESCO – Energy Service Company
ESG – Environmental, Social, and Governance
GHG – Greenhouse Gas
GRIHA – Green Rating for Integrated Habitat Assessment
HVAC – Heating, Ventilation, and Air Conditioning
IGBC – Indian Green Building Council
IEA – International Energy Agency
IPCC – Intergovernmental Panel on Climate Change

IPMVP – International Performance Measurement and Verification Protocol
ISO – International Organization for Standardization
LCA – Life Cycle Assessment
LCI – Life Cycle Inventory
LMC – Labour Market Consortium
LPD – Lighting Power Density
M&V – Measurement & Verification
MBE – Mean Bias Error
MNIT – Malaviya National Institute of Technology
NZC – Net Zero Carbon
NZE – Net Zero Energy
OPC – Ordinary Portland Cement
PSC – Portland Slag Cement
PPC – Portland Pozzolana Cement
PVC – Polyvinyl Chloride
RCC – Reinforced Cement Concrete
RMC – Ready Mix Concrete
SHGC – Solar Heat Gain Coefficient
SPA – Strategic Partnership Agreement
SRI – Solar Reflectance Index
TMT – Thermo-Mechanically Treated (Steel)
TR-h – Ton Refrigeration-Hour
U-value – Thermal Transmittance Value
UHI – Urban Heat Island
VAV – Variable Air Volume
VRF – Variable Refrigerant Flow
WGBC – World Green Building Council
WWR – Window to Wall Ratio

EXECUTIVE SUMMARY

India's building and construction sector contributes approximately 32% of the nation's total emissions, encompassing both operational and embodied carbon. Emissions primarily stem from materials like cement and steel and the energy consumed during building construction and operations. By 2050, India's total building floor area is expected to grow from 15.8 billion to 57.6 billion square meters — that's like adding the entire built-up area of the United States nearly twice over, or multiplying the entire building footprint of Denmark nearly 48 times.

To support this boom, India will need:

- 1,360 million metric tons of steel, enough to build 1,90,000 Eiffel Towers.
- 755 million metric tons of cement, enough to construct over 100 Great Walls of China (based on cement volume used in a comparable length).

This scale of development is like building a new Chicago every year between now and 2050 — not just in size, but in the massive demand for raw materials. Consequently, CO_2 emissions from buildings are expected to reach 245 metric tons by 2040. With limited alternatives to high-emission materials, the focus must shift to design efficiency, innovative construction technologies, and energy optimization to reduce emissions from both new and existing buildings.

The Confederation of Indian Industry (CII) and Danish Industry (DI) have jointly developed a comprehensive roadmap to accelerate the transition of Gujarat's commercial building sector towards net zero carbon emissions. By analysing both operational and embodied carbon impacts, the study has identified key interventions spanning energy efficiency, renewable integration, low-carbon materials, and sustainable operations.

These insights have been consolidated into targeted recommendations for building sector stakeholders, along with policy recommendations to support an enabling environment. This integrated technical and policy oriented approach is designed to guide Gujarat's commercial building sector on a practical and scalable pathway to a climate-resilient, net zero future.

Drawing on global net-zero pathways from the Paris Agreement, the study emphasizes actions such as transitioning to renewable energy, improving energy efficiency, and adopting sustainable building materials. With the building sector as a central focus, the report utilizes data collection, energy modelling, and lifecycle analysis (LCA) to evaluate the impact of Energy Conservation Measures (ECMs) like HVAC and lighting upgrades, advanced insulation, and renewable energy integration, highlighting their potential to reduce both operational and embodied carbon.

Environmental and financial analyses identify ECMs with high returns on investment, demonstrating that sustainable practices can deliver significant environmental benefits and remain economically viable. The implementation framework outlines immediate regulatory engagement, medium-term financial incentives, and long-term alignment with international ESG standards.

The study recommends for all new buildings to be designed green and for existing ones to have retrofitting for meeting or exceeding sustainability targets following Green Existing Building program to unlock 30-40% energy savings from the baseline. By adopting advanced measures and aiming for near Net Zero Energy performance, buildings can save over 70% energy by 2030, cutting carbon emissions in half and setting a bold benchmark for a sustainable future.

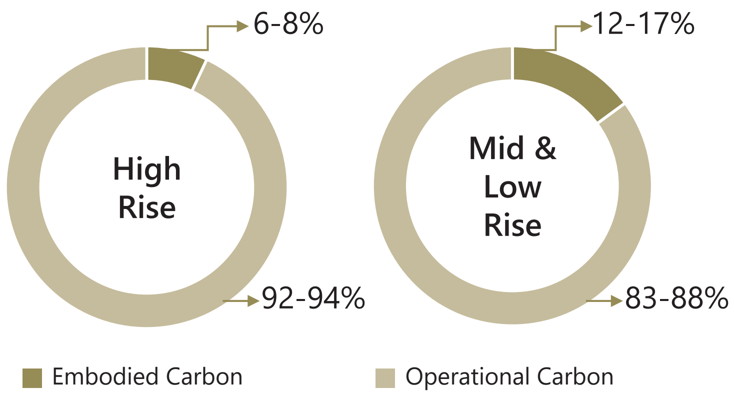


Figure 01 - Distribution of embodied and operational carbon – High-rise and mid-rise buildings

The study evaluated both embodied and operational carbon in high-rise and mid/low-rise buildings. In high-rise structures, steel and cement together account for approximately 88–92% of the total carbon footprint, while in mid and low-rise buildings, their contribution ranges from 70–85%.

With respect to embodied carbon, it has observed that cement and steel have overall 65-90% of embodied carbon footprint based on building typology. The study recommends adopting green procurement practices specially procuring low embodied carbon cement to reduce majority of embodied of carbon emissions in the commercial buildings of Gujarat. Green field/ new construction project shall aim to achieve lower carbon footprint in the range of 500-550 kgCO_2eq/sq.m (for major structural elements, façade and interior finishes).

State level government policies can support the industry to realise the benefits of Net Zero. It is recommended to regulate policies defining minimum energy efficiency standards, procurement of low-carbon building materials and equipment, performance monitoring and reporting of existing buildings and plan retrofitting, offer financial incentives and also mandate capacity building of professionals.

If Gujarat adds 5 million sq.m new commercial built-up area, 75,000–1,00,000 tonnes CO_2e compared to the baseline of 700 kg CO_2e/sq.m. by 2030, this could translate into 0.5–0.7 million tonnes CO_2e which would be avoided.

STRATEGIC PARTNERSHIP AGREEMENT

In 2017, the Confederation of Danish Industry (DI), United Federation of Workers in Denmark (3F) and the Danish Trade Union Development Agency (DTDA) came together to form the Labour Market Consortium (LMC) with the intention of engaging in a Strategic Partnership Agreement (SPA) with the Danish International Development Agency (DANIDA) under the Danish Ministry of Foreign Affairs. The Strategic Partnership Agreement was approved in 2017. Based on the agreement, the consortium makes use of the experiences from the Danish labour market model to support improvements of labour market conditions and private sector growth in emerging markets. The LMC has active partnerships in more than 30 countries around the globe. The overall objective of the Labour Market Consortium (LMC) and its local partners is to accelerate a just transition that promotes sustainable production and inclusive, gender balanced labour markets with full respect for workers' human rights, contributing to the creation of decent jobs and better opportunities in the labour markets in developing countries. The main assumption is that labour market organisations are key agents of the change needed to achieve a just transition. This assumption is based on the experience from Denmark that organised workers and employers who engage in constructive dialogue have the competencies to propose, design, and implement innovative and realistic solutions toward more sustainable production.

1.1 STRATEGIC INTERNATIONAL PARTNERSHIPS

DI and the other partners in the consortium always work in partnerships with like-minded organisations in partner countries by linking experiences from Denmark with partners' knowledge of the local context. The partners are thus the main drivers of change, and the LMC contributes to this development based on experiences from Denmark. DI always works through equal and mutually beneficial partnerships. Collaboration happens through the exchange of ideas, experience, and knowledge, as well as advisory assistance and joint international advocacy. DI has Strategic International Partnerships with 17 employers and business associations across South America, Africa, Asia, and Eastern Europe.

1.2 EU ESG REGULATIONS

In recent years, the global landscape has seen a significant shift toward Environmental, Social, and Governance (ESG) legislation, with the European Union (EU) leading the charge in formalizing and standardizing sustainability efforts. By converting voluntary sustainability standards into binding regulations, the EU has set a benchmark in addressing ESG issues, aligning these efforts with its goal of becoming carbon-neutral by 2050. As a result, large corporations operating within the EU are increasingly compelled to meet rigorous environmental, social, and governance standards. And, while these regulations are primarily aimed at companies within the EU, their impact extends far beyond. For companies outside the EU here among those in India, this regulatory framework poses both challenges and opportunities. With the EU being India's second-largest export partner, accounting for 16% of total exports, it is crucial to ensure that sustainability requirements do not become a barrier to trade relations between the EU and India.

Through active collaboration between DI and CII-IGBC, this project provides practical tools to advance green building practices in India and navigate the continuous evolving requirements, emphasizing critical areas such as energy efficiency, carbon reduction, and resource management. These efforts aim to enable Indian businesses to meet the EU's sustainability expectations, thereby maintaining market access while also strengthening their global competitiveness, ultimately, ensuring that sustainability enhances rather than hinders mutual economic growth and collaboration.

1.3 GREEN TRANSITION – THE KEY FOCUS

The focus of the engagement in each country varies depending on the capacities and priorities of our local partner organisation, and the context, country, and region in which the engagement takes place. The green transition is, however, at the core of all activities as it is believed to be a key competitive parameter in the future.

GLOBAL RESEARCH ON NET ZERO IN THE BUILDING SECTOR

Global research increasingly recognizes the building sector as a cornerstone of net zero transitions, accounting for nearly 40% of global energy-related carbon emissions. Studies by the International Energy Agency (IEA), the Intergovernmental Panel on Climate Change (IPCC), and other organizations emphasize that reducing both operational energy use and embodied carbon in materials is essential to achieving climate goals.

Key pathways include advanced energy efficiency measures—such as high-performance glazing, insulation, and smart energy management—alongside retrofitting existing buildings and expanding renewable energy in the built environment. In parallel, innovations in low-carbon construction materials, including green cement, recycled steel, and next-generation façade systems, are emerging as critical solutions to address embodied emissions.

Global assessments show that improving energy efficiency alone could deliver more than one-third of the emission reductions needed in the building sector by 2050, while material strategies such as low-carbon cement and recycled steel could cut embodied carbon by 40–50% in new construction. Retrofitting existing buildings, which represent the majority of the global building stock, offers some of the fastest and most cost-effective opportunities to reduce energy demand.

A critical dimension of net-zero building research is the application of circular economy principles, emphasizing design for disassembly, material reuse, and waste reduction. Organizations like the World Green Building Council (WGBC) highlight that applying life-cycle assessments (LCA) can significantly lower emissions by promoting sustainable material choices and resource efficiency. At the same time, research stresses that achieving net zero in buildings requires not only technological innovation but also supportive regulatory frameworks, financial incentives, and international collaboration to scale investment.

INDIA'S TRANSITION TOWARDS NET ZERO

India, the world's third-largest carbon emitter, plays a critical role in combating climate change. At COP26 in Glasgow (2021), Prime Minister Narendra Modi pledged net-zero emissions by 2070, a reduction of 1 billion tons of emissions by 2030, and a 45% cut in carbon intensity (from 2005 levels). A key challenge for India is decoupling economic growth from carbon emissions in its fuel-dominated energy system. The government is working to expand renewable energy, which now accounts for over 40% of total power generation. As the fourth-largest economy, set to become the third largest by 2032, India has a unique opportunity to adopt a low-carbon growth path unlike other major economies. Figure 2 shows GHG level and per capita emission levels.

The building and construction sector, with its fragmented value chain, poses significant challenges for decarbonization. The lack of data and transparency hampers effective emissions reporting. Efforts are underway to unite stakeholders, improve collaboration, and facilitate low-carbon practices in the industry. India has implemented policies to reduce operational carbon in the built environment, including incentives for rooftop solar adoption in the residential sector. Additionally, retrofitting existing buildings—a key strategy in many countries—can greatly enhance energy efficiency. Strengthening such incentives in India could accelerate progress. Achieving net-zero will require substantial domestic and international investment in clean energy, technology, and infrastructure, along with robust policies to drive this transition.

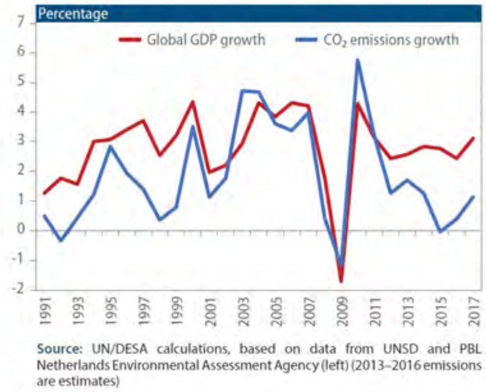


Figure 02 - GDP and CO_2 emission

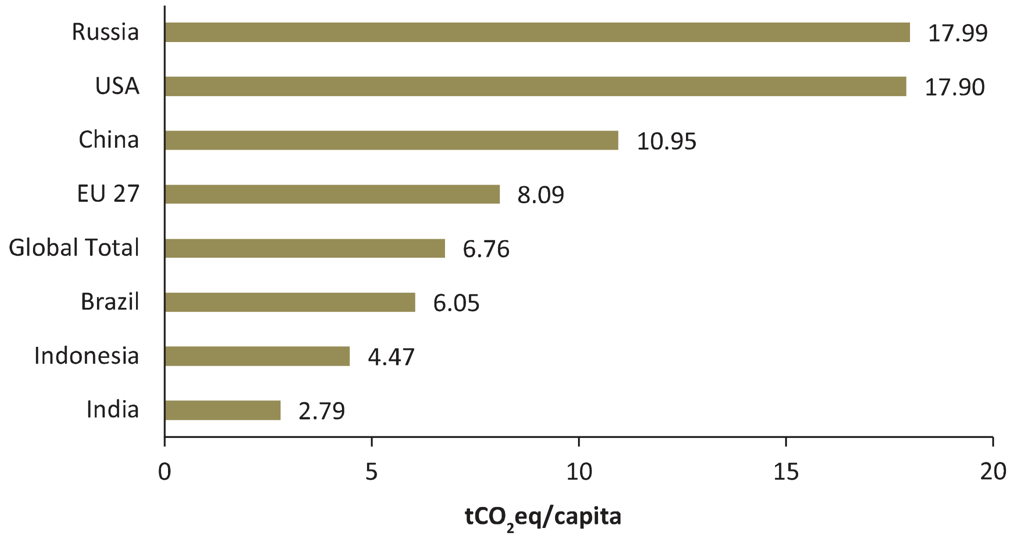


Figure 03 - tCO_2eq/capita

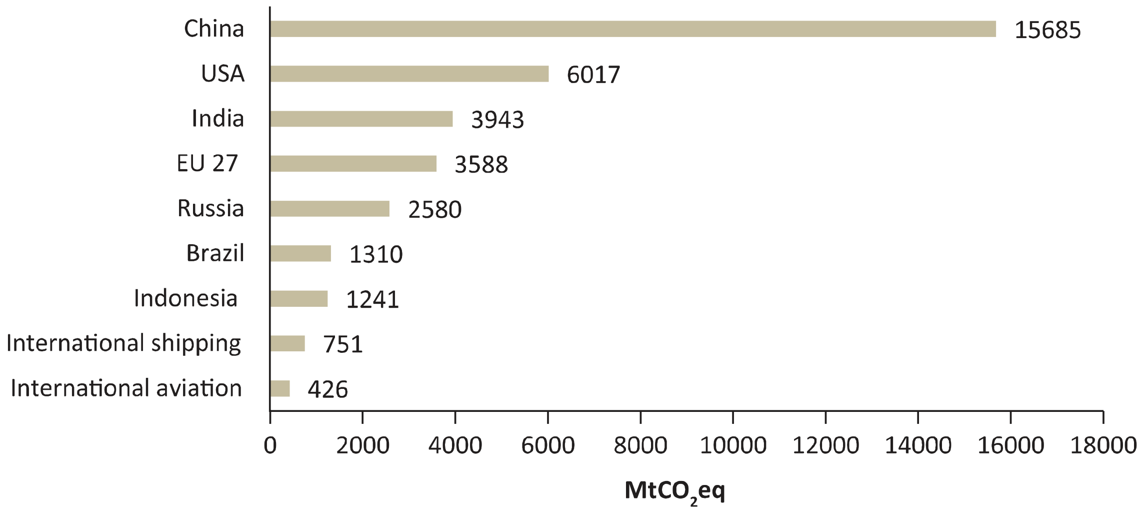


Figure 04 - GHG emissions at global level

PROJECT BACKGROUND – JOINT INITIATIVE OF CII AND DI

CII (Confederation of Indian Industries) and Danish Industry (DI) kicked-off collaboration in 2022 to develop roadmap for the building sector in Gujarat to achieve carbon neutrality and also to recommend measures which can be practiced by both green and brown field projects to embrace Net Zero goals. The project, "To facilitate Indian building sector to move towards net zero carbon so as to contribute to the Nation's mission on achieving carbon Neutrality by 2070", developed with a specific focus on mapping baseline emissions from various types of commercial buildings and facilitates projects in achieving Net Zero Energy performance. Further, the main objective of the project is to reduce carbon emission in commercial buildings, Gujarat. It aims to create a roadmap for faster adoption of Net Zero Concepts, with the goal of replicating the study across India.

India's commitment to achieving carbon neutrality by 2070 underscores the importance of initiatives like this. As part of this effort, comprehensive Life Cycle Analysis (LCA) of seven projects, and Measurement & Verification (M&V) of six projects, have been carried out, to identify embodied and operational carbon hence, the total carbon footprint of these case studies. These insights are used to develop effective strategies for reducing emissions, ultimately transforming them into net zero buildings. The understandings gained from these pilot projects serve as a foundation for scaling efforts to include a wider range of building types across India. By targeting one of the most carbon-intensive sectors, the construction industry, this initiative not only contributes to India's carbon neutrality goals however, also serves as a replicable model for other states.

4.1 GUJARAT TOWARDS NET ZERO

Gujarat, comprising of 6% of India's landmass, and home to ~5% of the population, with 43% of them residing in urban areas, is a significant player in India's economic landscape, accounting for 8.3% of the nation's GDP in 2022-2023. Renowned for its industrial strength and economic growth, the state is taking decisive steps towards a low-carbon, sustainable future, in line with India's Net-Zero target for 2070. Gujarat is focusing on policies that promote clean and renewable energy, encourage the manufacturing of low-carbon technologies, and support sustainable practices across key sectors such as transport, water, industry, and buildings.

4.2 PROJECT PARTNERS

Confederation of Indian Industry (CII)

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering with Industry, Government and civil society, through advisory and consultative processes. CII is a non-government, not-for-profit, industry-led and industry-managed organization. For more than 125 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII charts change by working closely with the Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialized services and strategic global linkages. With 62 offices, including 10 Centres of Excellence, in India, and 8 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and the USA, as well as institutional partnerships with 350 counterpart organizations in 133 countries, CII serves as a reference point for Indian industry and the international business community.

Indian Green Building Council (IGBC)

The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001. The vision of the council is, "To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025".

The council offers a wide array of services which include developing new green building rating programmes, certification services and green building training programmes. The council also organises the Green Building Congress, its annual flagship event on green buildings. The council is committee-based, member-driven and consensus-focused. All the stakeholders of the construction industry comprising of architects, developers, product manufacturers, corporate, government, academia and nodal agencies, participate in the council activities through local chapters. The council also closely works with several State Governments, the Central Government, the World Green Building Council, bilateral multi-lateral agencies in promoting green building concepts in the country.

Confederation of Danish Industry (DI)

The Confederation of Danish Industry (DI) is Denmark’s largest, most representative and most influential business and employers’ organization. DI represents more than 20,000 member companies, covering all sectors such as manufacturing, transport, energy, IT, health, life science, trade, building, construction, and professional services. DI is operating based on a core belief that a strong society needs strong companies – just as strong companies benefit from a strong society. Companies are crucial to maintaining the prosperity of all Danes, and to achieving societal goals such as a clean and carbon-neutral society. Some of DI’s main workstreams are therefore negotiating collective agreements with the Danish labour unions which is a crucial function in the strong Danish labour market model as well as improving business regulations at local, national, European, and international levels.

Exports account for almost 70% of Danish GDP, making the success of Danish companies in global markets crucial for Denmark’s economy. Every day, DI helps Danish companies turn global opportunities into successful business results – locally, nationally, and internationally. DI participates actively in numerous partnerships focused on green transition domestically as well as internationally and long-term partnerships and knowledge sharing are considered essential ways of working with key stakeholders to pursue long-term and mutually beneficial results. DI has over 900 employees at our main office in Copenhagen, Denmark. Furthermore, DI has offices in Brussels, Mumbai, Chennai, Berlin, New York, Shanghai, and Seoul.

DI India

DI India, a vital arm of DI's global network, has due to a growing Danish interest in the country, been located in Mumbai since 2008, with a recent expansion to Chennai in 2022. Serving as DI's boots on the ground, the Mumbai and Chennai offices specialize in facilitating Danish companies' entry into the Indian market, aiming to optimize success while mitigating risks. DI India has fostered numerous fruitful partnerships, solidifying its reputation as a trusted ally for Danish businesses navigating the complexities of the Indian market.

For ease of project implementation and to have continuous focus on the roadmap and execution, the project has collaboration with the M/s Savvy Green and M/s INI Studio Ahmedabad. Both the partners have expertise in assessment of Green and Net Zero buildings. Additionally, Prof Jyotirmay Mathur, Malaviya National Institute of Technology (MNIT) joined the initiative to provide technical assistance.

METHODOLOGY

The methodology outlines the systematic approach undertaken to develop a roadmap for achieving Net Zero status in commercial buildings, with a focus on office buildings in Gujarat. This comprehensive process combines data collection, building energy modelling and simulation, analysis of energy conservation measures (ECMs), financial analysis, and life cycle assessments (LCA), to provide actionable recommendations for reducing both operational and embodied carbon emissions. Figure 05 shows methodology adopted in the study.

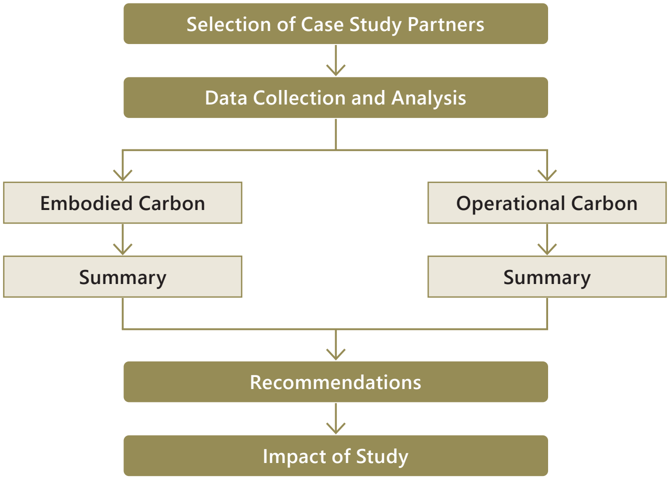


Figure 05 - Project Methodology

5.1 SELECTION OF CASE STUDY PARTNERS

Seven commercial office projects for Net Zero Energy and seven projects for Net Zero Carbon were selected as case study partners to represent diverse building typologies within Gujarat. These buildings were chosen to provide insights into various design, operational, and energy use patterns that influence energy consumption and carbon emissions.

S No.	Case Study Partner	Net Zero Carbon (NZC)	Net Zero Energy (NZE)
1.	Luthra Corporate Office	✓	✓
2.	Shivalik House	✓	✓
3.	Prakruti Building	✓	✓
4.	Titanium Building - INI Design Studio	✓	✓
5.	Pragya Tower	✓	✓
6.	Flex One Building	✓	NA
7.	GH Million Minds Building	✓	NA
8.	PSP House	NA	✓
9.	Shapath V	NA	✓

Table 01 - List of case study partners

5.2 DATA COLLECTION

Comprehensive data collection was carried out for each case study building to gather detailed information including:

- Detailed Bill of Materials (BOM/BOQ).
- Architectural and Engineering Drawings.
- Building envelope characteristics (e.g. insulation, window-to-wall ratio).
- HVAC systems and their efficiency.
- Lighting systems and technologies.
- Occupancy patterns and operational schedules.
- Historical energy consumption data.

This detailed data ensures accuracy in subsequent analysis and provides a foundation for both life cycle analysis and energy efficiency.

5.3 EMBODIED CARBON

The International Organization for Standardization (ISO) provides standards for LCA in ISO 14040 and 14044. These standards describe the four main phases of an LCA:

- Goal and scope definition.
- Life Cycle Inventory Preparation.
- Impact assessment.
- Results and Analysis.

Phase 1: Define Goal and scope definition	Define goal of the LCA by using the following questions and formulate LCA scope by defining the following: • Functional unit: Functional unit is a quantifiable unit which measures the product's footprint. • System boundaries: Select the life cycle phases (Cradle to gate, Cradle to grave, Cradle to Cradle) to be included in the LCA. • Methodological choices: Selection of standard code: EN15978: Sustainability of construction works – Assessment of environ-mental performance of buildings – Calculation method.
Phase 2: Life Cycle Inventory Preparation	The Life Cycle Inventory (LCI) involves creating detailed inventory of raw materials with proper bifurcations and uniform units. The quality of data is also verified in this step.
Phase 3: Impact assessment	The life cycle impact assessment is being done using the software. The impact category which is of focus for this study is Climate Change Category represents Carbon emission or Global Warming Potential.
Phase 4: Results and Analysis	This is the last phase where results of other phases are interpreted and are further analysed for • Major Contributions to carbon. • Identify any discrepancies.

5.4 OPERATIONAL CARBON

In this section the analysis of operational carbon is carried out. Using the data collection for various identified building typologies, the energy models are developed for each identified building. These models are carefully calibrated using real-world data to reflect actual building performance. The next section contains the calibration process, including the tools and techniques employed, is thoroughly discussed to ensure reliability in the energy simulations. The third section focuses on creating a baseline model for each building using reference values from energy codes and standards. These baseline models serve as benchmarks to compare the building's current performance against baseline and assess potential improvements.

After the baseline models are developed, several energy conservations measures (ECMs) are evaluated. This involves simulating various strategies to reduce energy consumption, such as improving insulation, upgrading HVAC systems, or incorporating renewable energy sources. The impact of these measures on the building's energy performance is analysed and discussed in detail. Finally, financial analysis is carried out for the different ECMs to evaluate their cost-effectiveness and accordingly, recommendations are made to guide the building stakeholders to take their projects towards Net Zero.

Figure 06 - Understanding Carbon

5.4.1 Building Energy Modelling

Developing energy models helps in assessing a buildings performance and identifying opportunities for improvement, particularly in the context of achieving net-zero energy goals.

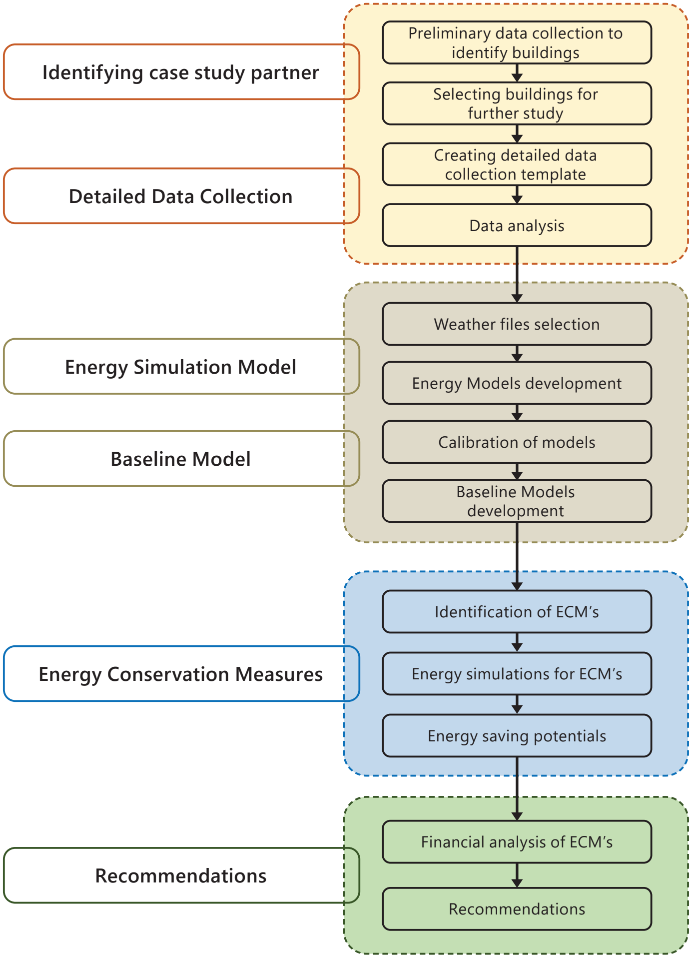


Figure 07 - Flow diagram of methodology for operational carbon study

Energy models simulate a building's behaviour in terms of energy use, taking into account factors such as climate, building envelope characteristics, energy systems, occupancy patterns, and operational schedules. These models allow for a detailed analysis of how energy flows through a building, helping to predict its energy consumption and efficiency under varying conditions. Figure 08 shows a simple representation of energy simulation model.

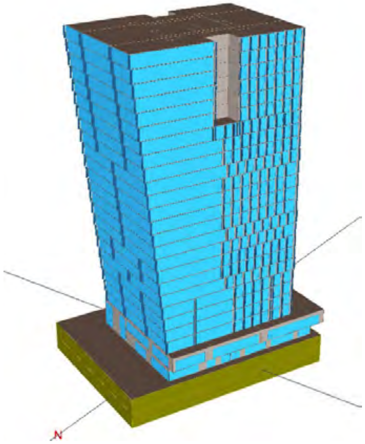


Figure 08 - 3D Building Energy Model

5.4.1.1 Assumptions

In the development of energy models, making assumptions is necessary to fill gaps in data and simplify complex systems, ensuring that the model is representing the actual one. These assumptions are based on best practices, standards, and available information, however, it is important to note that they introduce a degree of uncertainty. Common assumptions include factors like occupancy patterns, which might be generalized based on typical building use if exact schedules are not available, and thermostat settings for heating and cooling, which are often assumed to follow standard comfort levels (e.g., 24°C for cooling). Other assumptions involve the operational efficiency of building systems, such as HVAC, lighting, and appliances, particularly if specific data on their age or maintenance status is unavailable. In such cases, average efficiency levels based on equipment type or standard guidelines has be used.

5.4.2 Calibrated Energy Models

Energy models have been developed for each of the identified buildings using advanced simulation tools. The models are calibrated against real-world energy consumption data to ensure they accurately reflect actual building performance following IPMVP protocol. This calibration process involved:

- Comparing and eliminating gaps between simulation outputs and measured data.
- Use of actual operational schedules, equipment performance, and climate conditions to minimize deviations.

This process is essential for increasing the reliability of the model's predictions, particularly when it is used to evaluate energy conservation measures (ECMs) or propose design changes aimed at improving efficiency. Figure 09 shows process of calibrating an energy model.

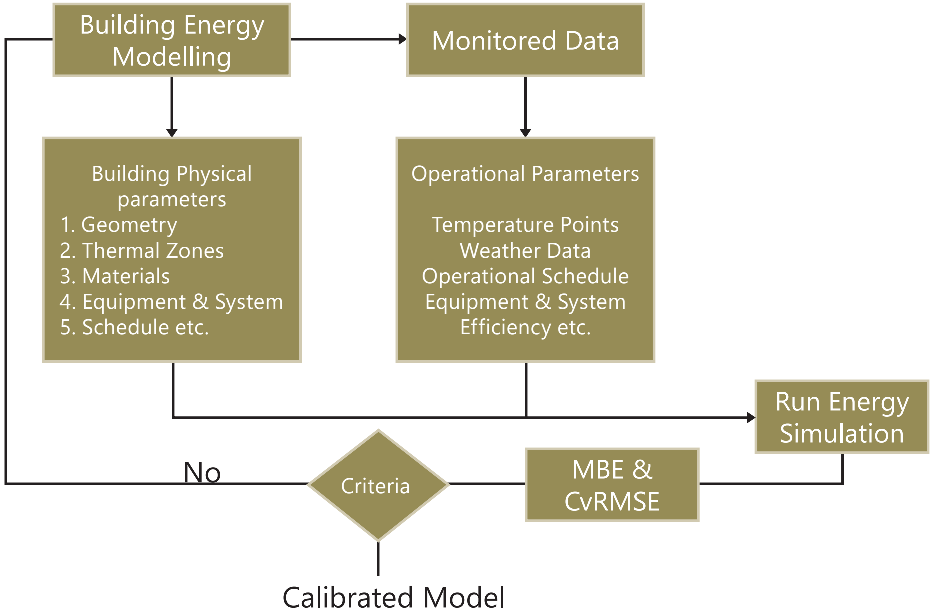
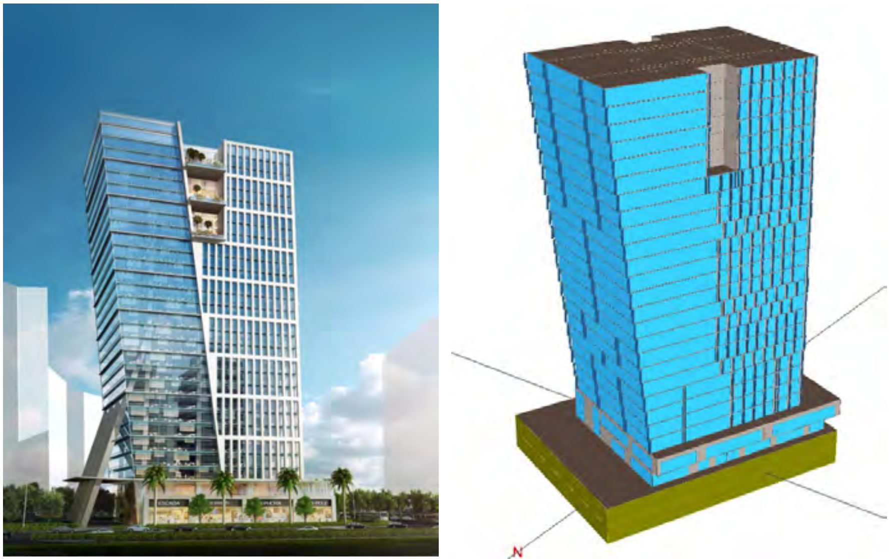


Figure 09 - Schematic illustration of calibration process

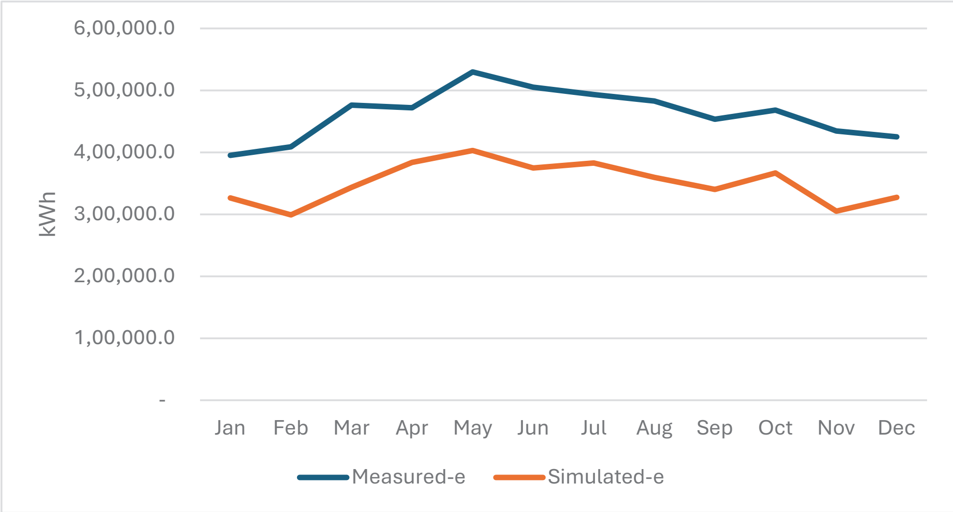
In energy modelling, it is important to define error limits between the actual energy consumption data and the simulated energy values to ensure that the model is both accurate and reliable. Error limits represent the acceptable range of deviation between the model's predictions and real-world energy performance and they are typically measured using metrics such as Mean Bias Error (MBE) and Coefficient of Variation of Root Mean Squared Error (CVRMSE). These metrics quantify the percentage difference between the simulated and actual energy use, helping to assess the model's accuracy. According to IPMVP, acceptable error limits for monthly calibration are generally within ±5% for MBE and within ±15% for CVRMSE.

When the difference between actual and simulated values falls within these defined limits, the model is considered well-calibrated and suitable for evaluating energy conservation measures or predicting future energy performance. Figure 10 & 11 shows calibration and performance comparison.

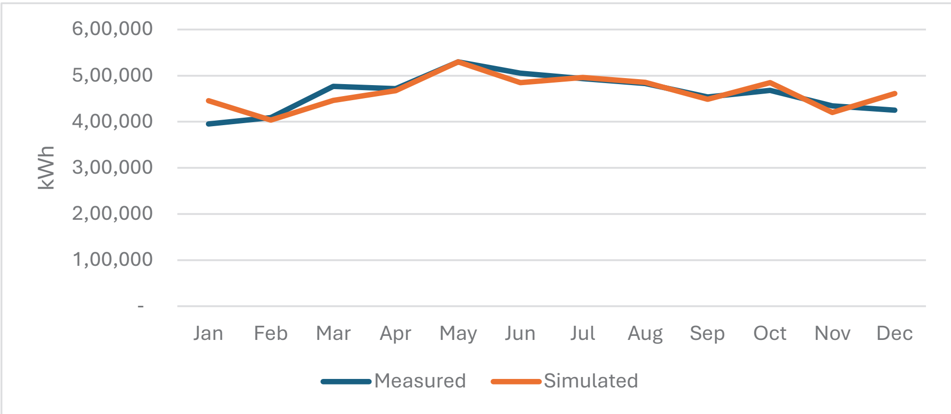


(a) *(b)*

Figure 10 - (a) Actual building, (b) Energy model of the building



(c) Before Calibration



(d) After calibration

Figure 11 - (c) energy consumption before calibration, (d) energy consumption after calibration

5.4.3 Baseline energy models

Baseline energy model was established to represent conventional building performance. This baseline serves as the reference point for evaluating the impact of proposed ECMs.

Exterior Wall	Roof	Glazing	LPD
2.1 W/m^2. k	1.5 W/m^2. k	SHGC: 0.6 U-value: 4 W/m^2. k	1 W/ft2
EPD	**HVAC (DX System)**	**Occupancy**	**Schedules**
As built	COP: 3	Actual Building Occupancy Nos.	Actual Operational Schedules

5.4.4 Energy Conservation Measures (ECMs)

Energy Conservation Measures (ECMs) are strategies or technologies that improve a building's energy efficiency. They range from HVAC upgrades and better insulation to optimized lighting and renewable energy integration. Essential to net-zero goals, ECMs lower energy demand while ensuring comfort and functionality. Implementation typically starts with an energy audit to identify inefficiencies. Common examples include high-efficiency HVAC systems, programmable thermostats, LED lighting, and envelope improvements like insulation and energy-efficient glazing to reduce heat loss or gain. These measures included:

ECMs

- Enhancing building envelope.
- Retrofitting HVAC systems.
- Incorporating energy-efficient lighting etc.

The impact of these measures are analyzed to identify average energy savings across all the case study buildings.

5.4.5 Financial Analysis of ECMs

Carrying out a financial analysis of Energy Conservation Measures (ECMs) is essential for determining their economic feasibility and identifying the most cost-effective options for improving a building's energy performance. This analysis typically involves evaluating the initial investment costs, potential energy savings, operational cost reductions, and the overall return on investment (ROI) associated with each ECM. Figure 12 shows the key factors affecting the financial aspect of a building.

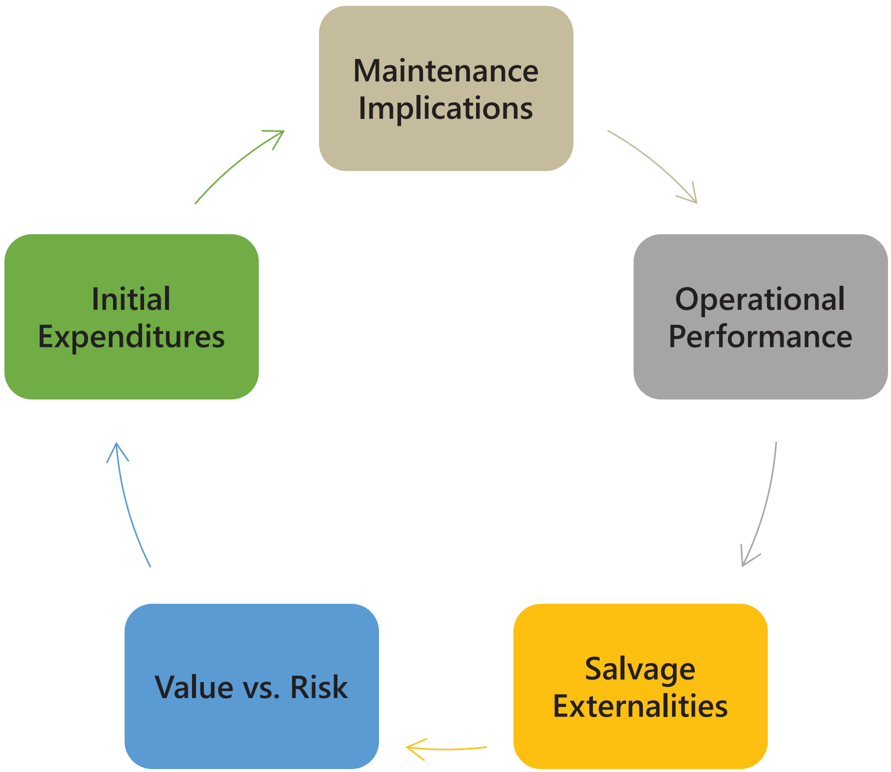


Figure 12 - Key factors of financial analysis

5.5 RECOMMENDATIONS

Based on the findings from the calibrated energy simulations, ECM evaluations, financial analyses, and LCA studies, actionable recommendations were developed for the building sector. These include:

1. Implementing cost-effective ECMs to optimize energy performance.
2. Transitioning to low-carbon construction materials.
3. Adopting renewable energy systems to offset remaining operational carbon emissions.

BASELINE MAPPING FOR EMBODIED CARBON IN BUILDINGS

6.1 LIFE CYCLE ASSESSMENT (LCA)

Life cycle assessment (LCA) is used to quantify the environmental impacts of a building which include Carbon Emission, Water Footprint, Waste and many other impact categories. Following section explain some of the terminologies used in a Life Cycle Carbon Analysis from a building perspective. Figure 13 demonstrates LCA stages and modules.

Figure 13 - Various stages and modules for LCA, Source: New Building Institute

Embodied carbon represents carbon emissions released during the lifecycle of building materials, including extraction, manufacturing, transport, construction, and disposal. Embodied carbon can be further broken down into 'upfront', 'in-use' and 'end-of-life' emissions. Upfront embodied carbon refers to 'the emissions caused in the materials production and construction phases of the lifecycle before the building or infrastructure begins to be used'.

In-use embodied carbon refers to 'emissions associated with materials and processes needed to maintain the building or infrastructure during use such as for refurbishments'. End of-life embodied carbon refers to 'the carbon emissions associated with deconstruction/demolition, transport from site, waste processing and disposal phases of a building or infrastructure's lifecycle which occur after its use'. Operational carbon refers to the emissions associated with energy used to operate and maintain the building or in the operation of infrastructure, including heating, hot water, cooling, ventilation, lighting systems, equipment and lifts.

6.2 APPROACH AND METHODOLOGY

Figure 14 defines approach and methodology adopted for carrying out LCA study of chosen building projects.

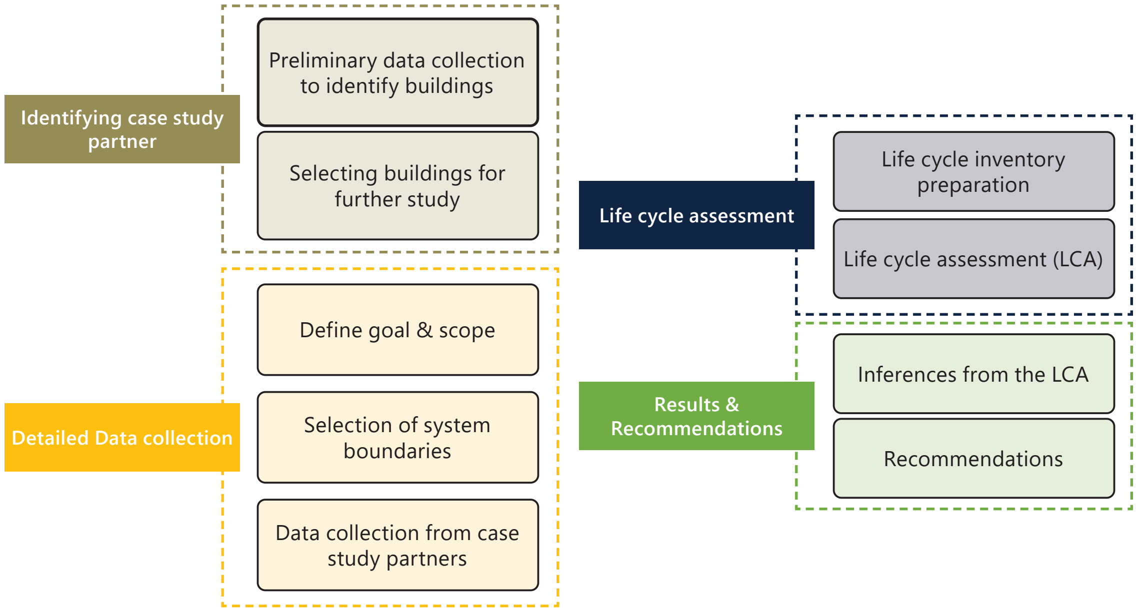


Figure 14 - Approach and methodology adopted for the LCA study

6.2.1 System Boundaries

The system boundary included to perform Life Cycle Assessment for the case study partners is as follows:

- A1 Extraction of Raw Materials
- A2 Transportation of Raw Materials
- A3 Manufacturing
- B4 + B5 = Material Replacement and Refurbishment
- B6 Operation Energy
- C1 + C2 + C3 + C4 = End of life Stage

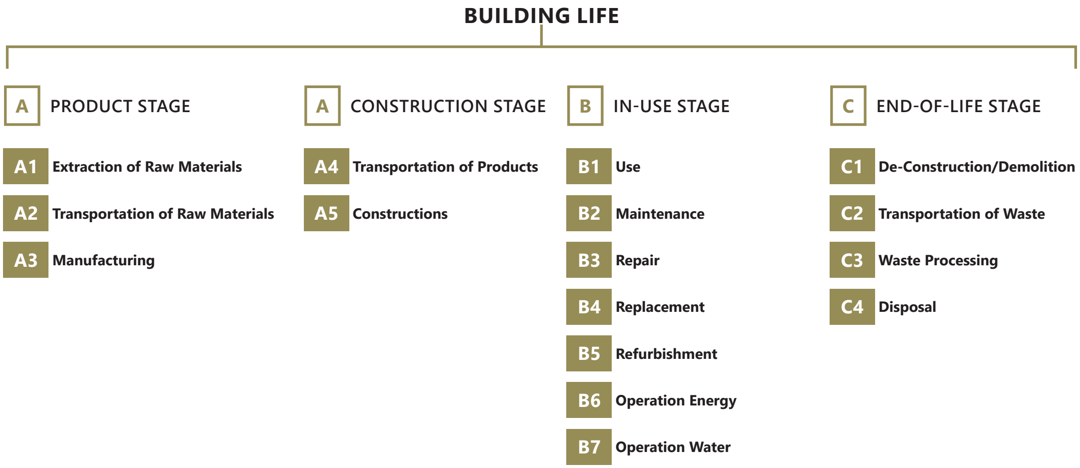


Figure 15 - System boundaries for the LCA – Product state, construction, in use state and end of life

6.2.2 Data Sources

The analysis performed relying on the following data sources for building information:

1

Raw Material (A1-A3)

Construction drawings, bills of quantities as shared by the case study partner.

2

Material transport distances (A4)

Material transport distance has not been considered as data was not available.

3

Construction and installation (A5)

Impacts are based on literature and conservative default values from the tool, as applicable.

4

Material impacts in use (B4-B5)

Material service lives are based on the typical values for the materials in question, which have been reviewed for relevance for the project. The values have been adjusted where necessary. Material maintenance and repair activities have not been included in the scope, materials have been assumed to be replaced in their entirety at the end of their service life.

5

Use phase energy consumption (B6)

Impacts are based on detailed energy analysis performed for this project.

6

Use phase water consumption (B7)

Impacts are omitted from this analysis due to unavailability of the data.

7

End of life impacts (C1-C4)

End of life impacts are based on the tool LCA's scenarios which represent the typical end of life processing for material types.

CASE STUDY PARTNERS

> *At Savvy, we believe development must serve a larger purpose - improving quality of life while protecting the environment. Our approach combines forward-looking design, responsible resource use, and a commitment to creating spaces that remain valuable for decades!*
>
> \- Sameer Sinha,
> Founder & MD, Savvy Group

PRAGYA TOWER (GANDHINAGAR, GUJARAT)

The Pragya Tower is a G+24 commercial office space with 2 basements and the operation started in 2021. The Gross floor area is 51,306 sq.m with a window wall ration of 68%. The major materials considered as part of LCA study are Steel reinforcements, Ready Mix Concrete, Plain Cement Concrete, Structural Steel Elements, Façade Glass, Interior paints & coating, floor tiles & wall claddings, AAC blocks and it's mortar requirement. Sealants and glass adhesives were also considered as part of the study. The operational carbon component is calculated for the year 2022 and the service life considered is 50 years. The maintenance phase and end of life cycle phase was analysed based on default scenarios present in the calculation tool.

KEY FINDINGS

The major contributions are from concrete and steel TMT with 40.35% and 39.99% respectively. The RMC mix consists of PPC and PSC based cement. Since it's a high-rise building, the structural steel component led to 2.21% of the total embodied carbon.

Though the building has huge façade elements with DGU glasses of 7.24% contribution to total carbon, there is significant reduction in operational carbon and overall embodied carbon.

The contribution from plastering and mortar is of 1.44% and it is less because of the usage of Ready-Mix Plaster and Block adhesives. The interior paints utilised are water-based paints which lead to the reduction of total paint quantity when compared with solvent based paint. This led to reduction in the embodied carbon component.

Embodied Carbon (A1-A3) ($kgCO_2e/m^2$)	Operational Carbon for 50 years (B6) ($kgCO_2e/m^2$)	Maintenance Phase for 50 years (B4-B5) ($kgCO_2e/m^2$)	End of Life stage (C1-C4) ($kgCO_2e/m^2$)	Total Life Cycle Carbon for 50 Years ($kgCO_2e/m^2$)	Whole Building Life Cycle Carbon per year ($kgCO_2e/m^2$/year)
490.00	5,724.00	7.95	10.06	6,232.01	124.64
7.86%	91.85%	0.13%	0.16%		

Table 02 - Whole Building Life Cycle Carbon for Pragya

"The DI Track-II project has significantly contributed to improving the sustainability performance of our existing office building by identifying effective strategies for energy conservation. Through data-driven analysis of both operational and embodied carbon, the initiative offered valuable insights and practical recommendations. This collaboration reinforces our commitment to environmental stewardship and aligns with our broader corporate social responsibility and global sustainability goals.

- Bharat Borse, CMD - Deputy Manager -EHS, Luthra Group

LUTHRA CORPORATE OFFICE (SURAT, GUJARAT)

This two-story corporate office was constructed in 2009, and the interiors were refurbished in 2020. So the Core & Shell is 16 years old. It's an unsymmetrical building with gross floor area of 2,995 sq.m and window to wall ratio is 17%. The building envelope is a combination of clay brick and AAC blocks.

The major materials considered as part this study are Steel reinforcements, Cement for structural concrete and non-structural elements (plastering, brick laying). The exterior façade includes louvers, claddings of terracotta and aluminium, glass. The flooring types include carpet, vitrified tiles and wooden laminate flooring. The building has a glass dome structure at the top. Water based paints are used for both interior and exterior.

KEY FINDINGS

- The Core & Shell was constructed in 2009 which utilised steel with higher embodied carbon and ordinary Portland cement is used in all structural elements.
- Also, the utilisation of clay brick increased the quantity of bricks used.
- When looking at individual material wise, 3 elements lead to 75.5% of the total embodied carbon. The next highest of 12.85% is due to aluminium louvers in the façade.
- The interior paints utilised are water-based paints which lead to the reduction of total paint quantity when compared with solvent-based paint. This led to reduction in the embodied carbon component. The reduced impact of usage of terracotta cladding in the facades is reflected in the operational carbon.
- It is observed that the office is having rooftop solar installation of 200 kWp capacity which can meet there 98% of total electricity consumption. Therefore, practically the operational carbon is close to nil for this building.

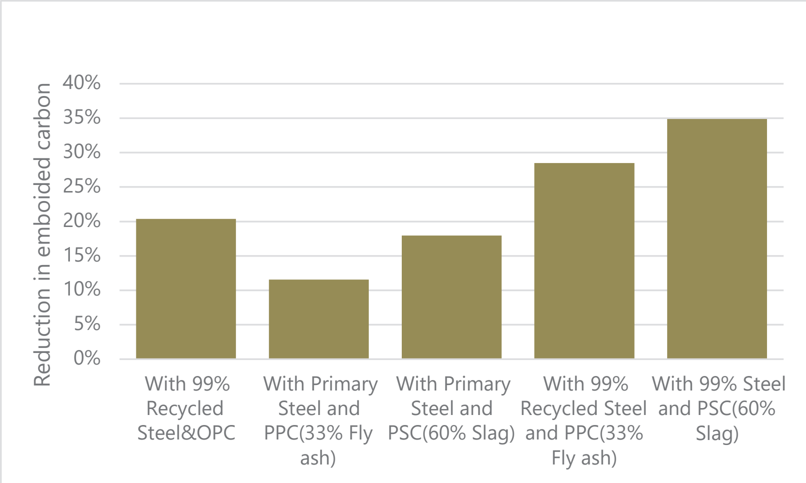


Figure 16 - Measures to reduce embodied carbon emission

Scenario	Description	LCA results	Reduction in embodied carbon
Case 1	With 99% Recycled Steel & OPC	461	20%
Case 2	With Primary Steel and PPC (33% Fly ash	512	12%
Case 3	With Primary Steel and PSC (60% Slag)	475	18%
Case 4	With 99% Recycled Steel and PPC (33% Fly ash)	414	28%
Case 5	With 99% Steel and PSC (60% Slag)	377	35%

Table 03 - Embodied Carbon Reduction Scenarios

Embodied Carbon (A1-A3) ($kgCO_2e/m^2$)	Operational Carbon for 50 years (B6) ($kgCO_2e/m^2$)	Maintenance Phase for 50 years (B4-B5) ($kgCO_2e/m^2$)	End of Life Stage (C1-C4) ($kgCO_2e/m^2$)	Total Life Cycle Carbon for 50 Years ($kgCO_2e/m^2$)	Whole Building Life Cycle Carbon per year ($kgCO_2e/m^2/year$)
559.00	3,733.00	48.08	4.57	4,344.65	86.89
12.87%	85.92%	1.11%	0.11%		

Table 04 - Whole Building Life Cycle Carbon

> *At the core of our vision is 'Growing Responsibly' - a principle that balances ambition with accountability. We strive to shape developments that not only meet today's needs but also safeguard resources and opportunities for generations to come.*
>
> - Taral Shah, MD, Shivalik Group

SHIVALIK HOUSE (AHMEDABAD, GUJARAT)

Shivalik House is constructed in year 2011 and interior were upgraded in 2021. It is a G+3 building with gross floor area of 2,430 sq.m and a basement for parking. The Window Wall Ratio (WWR) is 36.3% with a combination of DGU glass, structural glass of laminated type and clear glass. The building envelope is of clay brick and all the structural elements use steel TMT and OPC cement for RCC. Floor tiles and wall claddings are of vitrified type. The interiors like false ceiling, insulations were not considered.

KEY FINDINGS

- The combined impact of steel and cement is 71% with cement contributing close to 42.2%. This high impact of cement is due to the retaining wall structure in the basement apart from other structural elements.
- Another 5% contribution is from cement used in plastering, tile laying and bricklaying works.
- The impacts from standard clay brick led to 15.46% of embodied carbon due to its higher quantity.
- The reduction in impact is due to usage of laminated glasses and DGU glasses are observed in the operational carbon, similar to other buildings.

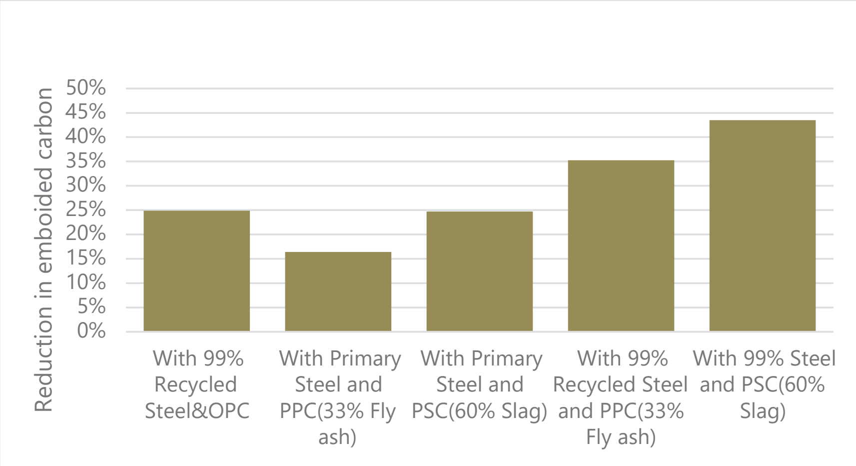


Figure 17 - Measures to reduce embodied carbon emission, Shivaliks

Scenario	Description	LCA results	Reduction in embodied carbon
Case 1	With 99% Recycled Steel & OPC	435	25%
Case 2	With Primary Steel and PPC (33% Fly ash)	484	16%
Case 3	With Primary Steel and PSC (60% Slag)	436	25%
Case 4	With 99% Recycled Steel and PPC (33% Fly ash)	375	35%
Case 5	With 99% Steel and PSC (60% Slag)	327	44%

Table 05 - Embodied Carbon Reduction Scenarios

<table>
<tr><th>Embodied Carbon (A1-A3) ($kgCO_2e/m^2$)</th><th>Operational Carbon for 50 years (B6) ($kgCO_2e/m^2$)</th><th>Maintenance Phase for 50 years (B4-B5) ($kgCO_2e/m^2$)</th><th>End of Life Stage (C1-C4) ($kgCO_2e/m^2$)</th><th>Total Life Cycle Carbon for 50 Years ($kgCO_2e/m^2$)</th><th>Whole Building Life Cycle Carbon per year ($kgCO_2e/m^2/year$)</th></tr>
<tr><td>544.00</td><td>3,510.00</td><td>32.88</td><td>4.94</td><td rowspan="2">4,091.82</td><td rowspan="2">81.84</td></tr>
<tr><td>12.87%</td><td>85.78%</td><td>0.80%</td><td>0.12%</td></tr>
</table>

Table 06 - Whole Building Life Cycle Carbon for Shivalik


shivalik
HOUSE
Rental income from day one
shivalik

> *The value of this study lies not just in its conclusions, but in its methodology—a replicable, data-driven framework for quantifying and reducing carbon in buildings. In an era when net zero risks being reduced to a slogan, this initiative restores meaning through rigor and transparency. It empowers both the public and private sectors with actionable insight, creating a shared language of sustainability.*
>
> - Jayesh Hariyani, CMD - Founding Principal, INI Design Studio

TITANIUM BUILDING - INI DESIGN STUDIO (AHMEDABAD, GUJARAT)

Titanium Building is a multi-tenant occupied building constructed in 2009. It is G+9 storey and two basements with a gross floor area of 11,734 sq.m. The interiors fitouts were retrofitted in different timelines as per the tenant's requirement. So, except floor tiles, wall claddings, carpet tiles and paints, all the other interior materials were not considered as part of the study. The Window Wall Ratio (WWR) is of 68% with clear glass in window systems and Structural Glazing in façade elements. Some part of external wall area is with rough plaster mix for architectural purposes.

KEY FINDINGS

Similar to other buildings, cement and steel contribute significantly to the overall impact, accounting for 81%, with cement alone contributing 45%. This is primarily due to the presence of retaining wall structures in the basement.

Clay bricks contribute around 7% of the impact, influenced by the higher window-to-wall ratio.

The next highest contribution, at 5%, comes from the external plaster. This is rough plaster, which has a higher cement content compared to conventional smooth-face plaster.

Façade glass elements contribute 2.83% to the total embodied carbon. This relatively high value is due to the use of structural glazing with a high U-value, which also increases the operational carbon impact.

Interior paints contribute approximately 0.02% — a very low value — owing to the use of water-based paints.

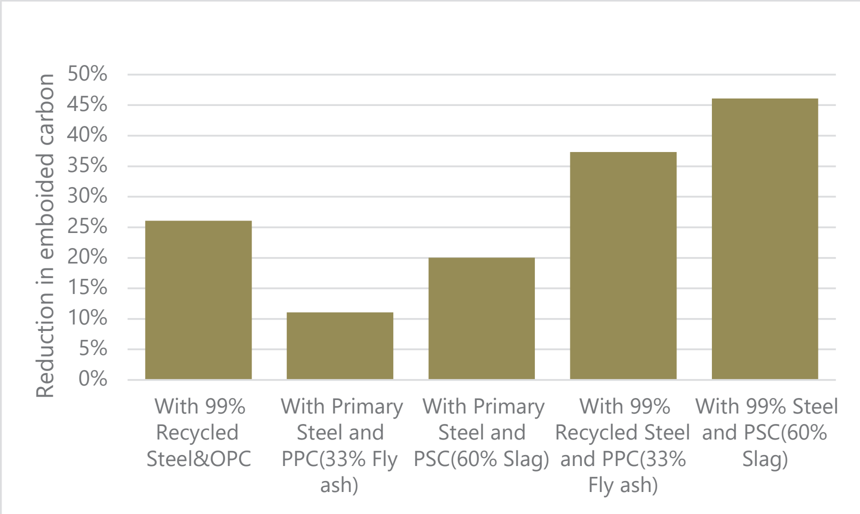


Figure 18 - Measures to reduce embodied carbon emission, Titanium - INI

Scenario	Description	LCA results	Reduction in embodied carbon
Case 1	With 99% Recycled Steel & OPC	428	26%
Case 2	With Primary Steel and PPC (33% Fly ash)	515	11%
Case 3	With Primary Steel and PSC (60% Slag)	463	20%
Case 4	With 99% Recycled Steel and PPC (33% Fly ash)	363	37%
Case 5	With 99% Steel and PSC (60% Slag)	312	46%

Table 07 - Embodied Carbon Reduction Scenarios

Embodied Carbon (A1-A3) ($kgCO_2e/m^2$)	Operational Carbon for 50 years (B6) ($kgCO_2e/m^2$)	Maintenance Phase for 50 years (B4-B5) ($kgCO_2e/m^2$)	End of Life Stage (C1-C4) ($kgCO_2e/m^2$)	Total Life Cycle Carbon for 50 Years ($kgCO_2e/m^2$)	Whole Building Life Cycle Carbon per year ($kgCO_2e/m^2/year$)
579.00	8,001.50	30.51	4.87	8,615.88	172.32
6.72%	92.87%	0.35%	0.06%		

Table 08 - Whole Building Life Cycle Carbon for Titanium - INI

"Green building is more than just an office space — it's a daily reminder that sustainability and productivity go hand in hand. With better daylight, cleaner air, and efficient energy systems, we've created a workplace that boosts well-being, reduces costs, and reflects our commitment to a healthier planet!

- Seema Abhale, Partner,
Prakruti Environmental Engineers

PRAKRUTI BUILDING (VADODARA, GUJARAT)

Prakruti is a G+4 storey and one basement with a gross floor area of 1,073 sq.m. The ground floor is a commercial supermarket, and the rest is office and lab. This is a relatively newly operated building (2019) compared to other case study partners. The WWR is 73% with a combination of DGU and single glazed glass in the façade. The cement used in the concrete is of OPC type.

The building envelope is composed of sand-based fly ash brick. Some of the exterior walls and terrace is plastered with two coats of rough sand plaster. The majority of flooring is of vitrified tiles and interior paints are water based.

KEY FINDINGS

It is observed that the retaining walls in the basement has been over designed with higher diameter of bars and higher concrete quantity.

As per the structural drawings the retaining wall was designed for a higher Seismic Zone though Vadodara falls under zone III seismic zone. Therefore, the contribution from steel and cement itself is amounting to 83% when compared with standard 70-75% contribution.

The next major contribution is due to a special plaster mix - two coats of rough sand plaster for architectural purpose. This leads to nearly 9.3% carbon emission.

The next higher emission is from sand-based fly ash brick (30% fly ash) which contributes 5.7% to the total embodied carbon.

Since the utilities and other electrical installations are relatively new (2019), the operational carbon component is less when compared similar building typology and area with older installations. This leads to reduction in the Whole Building life cycle carbon per annum.

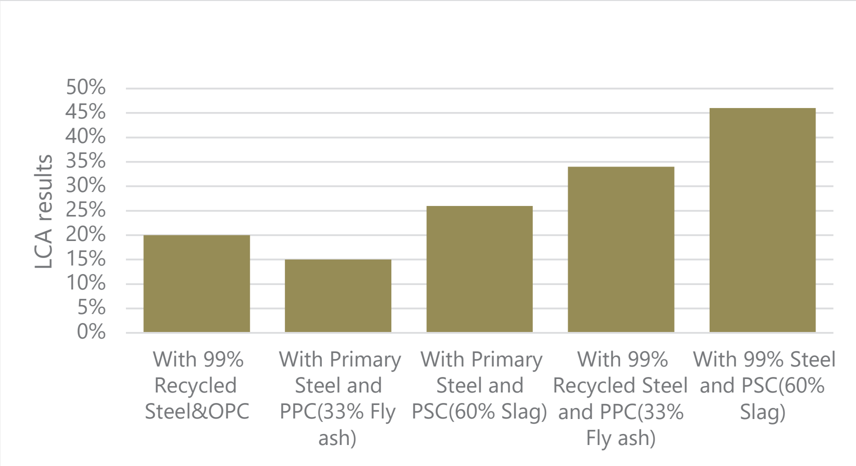


Figure 19 - Measures to reduce embodied carbon emission, Prakruti

Scenario	Description	LCA results	Reduction in embodied carbon
Case 1	With 99% Recycled Steel & OPC	493	20%
Case 2	With Primary Steel and PPC (33% Fly ash)	524	15%
Case 3	With Primary Steel and PSC (60% Slag)	453	26%
Case 4	With 99% Recycled Steel and PPC (33% Fly ash)	404	34%
Case 5	With 99% Steel and PSC (60% Slag)	333	46%

Table 09 - Embodied Carbon Reduction Scenarios

Embodied Carbon (A1-A3) ($kgCO_2e/m^2$)	Operational Carbon for 50 years (B6) ($kgCO_2e/m^2$)	Maintenance Phase for 50 years (B4-B5) ($kgCO_2e/m^2$)	End of Life Stage (C1-C4) ($kgCO_2e/m^2$)	Total Life Cycle Carbon for 50 Years ($kgCO_2e/m^2$)	Whole Building Life Cycle Carbon per year ($kgCO_2e/m^2/year$)
613.00	3,012.50	15.84	6.15	3,647.49	72.95
16.81%	82.59%	0.43%	0.17%		

Table 10 - Whole Building Life Cycle Carbon for Prakruti


PRAKRUTI
PRAKRUTI
aadhaar

FLEXONE is an IGBC Platinum pre-certified GRADE-A Commercial Building, making sustainability a top priority. From Material Selection, Building Orientation to Solar shading, many aspects of FLEXONE embody Sustainability. It has been optimized for operational efficiency and designed to achieve energy efficiency parameters.

- Shaan Zaveri,
MD, Collated Ventures

FLEX ONE BUILDING (GANDHINAGAR, GUJARAT)

Flex One is an under construction building whose construction works commenced in 2023. It is G+20 storey building with two basements and a gross floor area of 41,669 sq.m. Therefore, only the embodied carbon component is considered, and operational part is not considered for LCA study. The WWR is 48.9% with a combination of DGU and single glazed reflective glass in the façade. The foundation comprises concrete with fly ash-based cement.

The Core & Sheel comprises of Primary steel and RMC ranging from M25-M40. The RMC mix consist of fly ash-based cement and some fly ash as additives. The building envelope comprises AAC blocks. The project also utilized block adhesives and ready-mix plaster.

Embodied Carbon for Flex One (A1-A3): 547 kgCO_2e/sqm

KEY FINDINGS

The concrete used in substructure is of M40 grade and is of mat type. This is leading to 30% of embodied carbon. The rest is from RMC used in superstructure and Steel TMT.

It is observed that, the usage of Ready-mix plaster and block adhesives have reduced the quantity required and this leads to lower carbon emission contribution of 0.04% and 0.1% respectively.

The building envelope comprises of AAC block whose contribution is 3.09%.

“At Ganesh Housing, we see sustainability as a core part of responsible urban development. By prioritising efficient design, low-impact materials, and long-term performance, we aim to ensure our projects align with the shift towards a low-carbon built environment.

- Shekhar Patel, MD, Ganesh Housing

GH MILLION MINDS BUILDING (GANDHINAGAR, GUJARAT)

GH Million Minds is also an under construction building whose construction work was commenced in 2023. It is a G+16 storey building with two basements and a gross floor area of 84,592 sq.m. Therefore, only the embodied carbon component is considered, and operational part is not considered for LCA study. The WWR is 68% with a combination of DGU, aluminium claddings and aluminium spandrels in the façade. The horizontal roof slabs are precast and some vertical precast wall elements are also used with M40 and M30 grade of concrete. The other structural elements are of RMC with foundation using flyash based cement.

The building envelope comprises AAC blocks. The plastering comprises of a combination of gypsum plaster and ready-mix plaster. Apart from this block and tile laying adhesives are used. Flooring comprises of a combination of vitrified tiles, marble and granite. Water based paint are used for both exterior and interior.

Embodied Carbon for GH Million Minds (A1-A3): 593 kgCO_2e/sqm

KEY FINDINGS

The combined impact of RMC, steel and precast elements is around 91% and it is higher than the normal 70-75% contribution. This is due to 19% contribution from the vertical precast wall elements.

The combined usage of Gypsum Plaster and Ready-Mix Plaster have contributed to lower overall embodied carbon which is 0.01% only.

The contribution from AAC blocks is also reduced to 1% due to precast wall elements.

Though the usage of Aluminium Spandrels and Aluminium claddings has reduced the quantity of Structural glazing used the embodied carbon from façade element has increased.

6.4 KEY OBSERVATIONS FROM THE LCA STUDY

Year	WWR, %	Study Partner	Gross Floor Area (sqm)	Floor	Embodied Carbon ($kgCO_2e/m^2$)
2009	17	Luthra	2,995	G+2	559.00
2009	68	Titanium - INI	11,734	G+9 & 2B	579.00
2011	36.3	Shivalik	2,430	G+3 & 1B	544.00
2019	73	Prakruti	1,073	G+4 & 1B	613.00
2020	68	Pragya	51,306	G+24 & 2B	490.00
2024	48.9	Flex One	41,669	G+20 & 2B	547.00
2024	68	GH Minds	84,592	G+16 & 2B	593.00

Table 11 - Embodied carbon for case study chosen for the study

Operational vs Embodied Carbon: An important observation from the LCA study is the distribution between operational and embodied carbon among high rise and low rise/mid-rise buildings, as represented in the Figure 20.

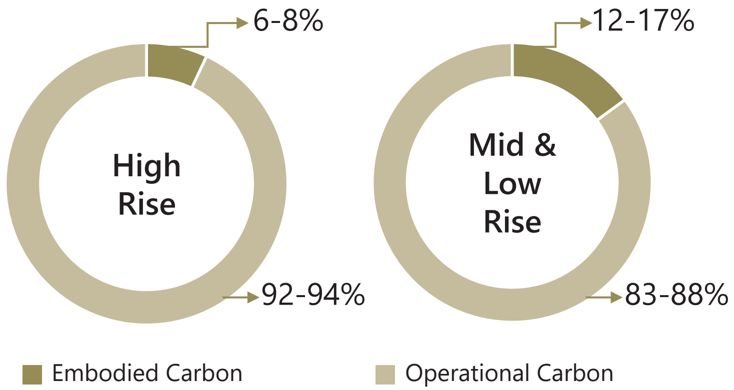


Figure 20 - Distribution of embodied and operational carbon – High-rise and mid-rise buildings

HIGH RISE BUILDINGS

Steel and Cement contribution nearly 88% to 92%

From a whole-building perspective, embodied carbon is lower in projects that incorporate optimized exterior glazing compared to those that do not.

Horizontal Precast Elements in slabs reduces the overall embodied carbon foot-print.

However Vertical Precast Wall Elements increases the overall embodied carbon.

Finishes: Ready-mix plasters, block adhesives & tile adhesives reduce the cement quantum thus reducing embodied carbon.

LOW AND MID-RISE BUILDINGS

Steel & Cement contribution 70% to 85%

Plastering, Partitions and Painting have a major contribution of 4%-6% of total embodied carbon.

The contribution from Carpet usage is alone 5%-7% of total embodied carbon.

Water-based paints have a much lower impact, as their higher spread rate reduces the quantity required per square metre compared to solvent-based paints.

Low Rise/Mid-Rise vs High-Rise Material Contribution:

Based on the results obtained, the range of contribution from major materials were mapped to the total embodied carbon. The following results were obtained for both high rise and low/mid-rise buildings. Steel, RMC, precast do have the highest contribution to carbon footprint. Figure 21 and Figure 22 show carbon footprint by different material in high and mid-rise buildings.

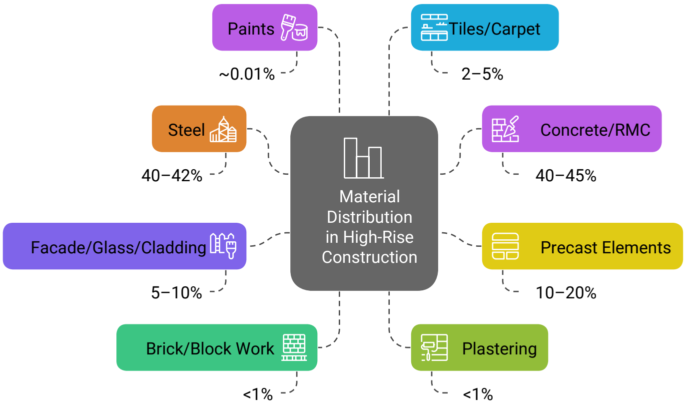


Figure 21 - Material matrix for embodied carbon – High-Rise Buildings

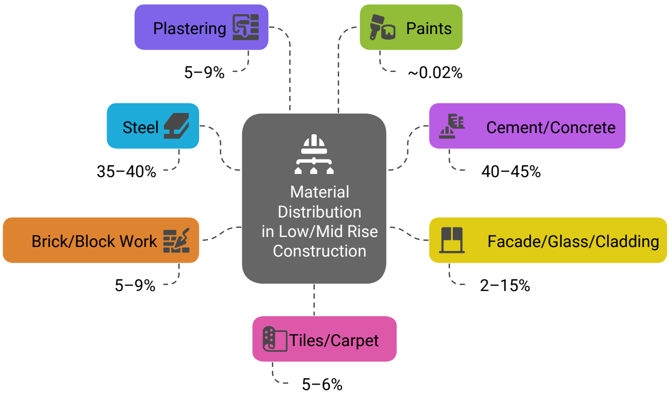


Figure 22 - Material matrix for embodied carbon – Low/Mid-Rise Buildings

Building age	The age of the building has a significant impact in the total embodied carbon and major difference is reflected in the Operational carbon. The materials used like normal cement plastering, OPC cement, Steel TMT, glass, solvent based paint have higher impact.
Way of Concrete Application	The usage of concrete in different forms like normal concrete, RMC & Precast have different impacts. In the case of high-rise building, usage of RMC & Precast in horizontal elements is more efficient. However, a precast vertical element leads to higher embodied carbon.
Steel	Usage of steel with recycled content reduces embodied carbon both at a unit level and at a building level.
Façade	Though impact of DGU glass is higher at per unit level, it significantly reduces at operational level and whole building's embodied carbon. Usage of reflective glass of single glazed type also leads to significant saving in operational carbon component.
Finishes	Ready-mix plaster has very less impact when compared to a convention plaster mix. This reduces the cement requirement. The same is applicable for block adhesives and tile adhesives. The contribution to total embodied carbon from paint is very minimal due to usage of water-based paint which has high spread range. So the quantum of paint required per sq.m is less when compared with solvent-based paint.
Flooring	Usage of carpet tiles with nylon PVC backing increases the overall embodied carbon of the building. It varies from 5% to 6% contribution to total embodied carbon when compared with 1% to 2% contribution from usage of vitrified tiles.

OPERATIONAL CARBON FOR BUILDINGS

This report analyses energy consumption patterns in several buildings in Gujarat and evaluates the impact of implementing Energy Conservation Measures (ECMs). By utilizing real-world data collected from operational buildings, the study aims to provide actionable insights into energy efficiency strategies that can be directly applied to similar buildings in the region.

Figure 23 presents a stepwise process for energy analysis and optimization in buildings. It follows a structured approach starting with building selection, followed by data collection, energy model development, and calibration to ensure accuracy. Then, Energy Conservation Measures (ECMs) are identified based on building type/size and further analyzed. Financial analysis is conducted to assess the feasibility, leading to financial recommendations. Finally, the process concludes with energy-saving estimation, evaluating the impact of the proposed measures.

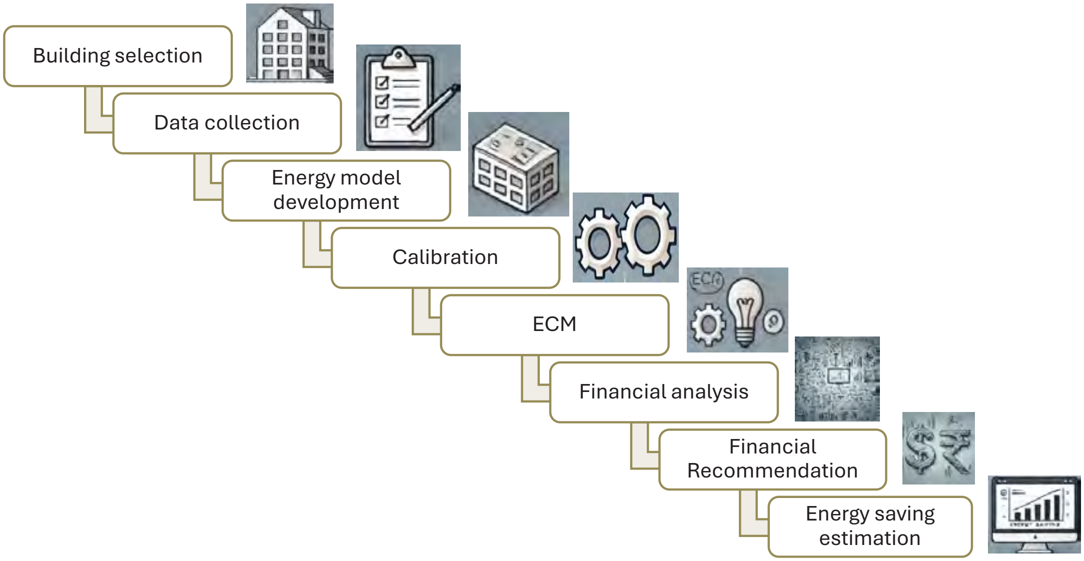


Figure 23 - Methodology for ECM analysis

7.1 MEASUREMENT & VERIFICATION (M&V)

A well-calibrated energy model ensures accuracy by aligning simulations with real-world data, especially for Net Zero Energy (NZE) targets. Baseline models help evaluate improvements, while Energy Conservation Measures (ECMs) enhance efficiency through strategic changes. Financial analysis determines their cost-effectiveness, supporting informed decisions in energy-efficient design, retrofitting, and policy reform. This section explores the role of energy modelling, ECMs, and financial analysis in achieving sustainable, high-performance buildings.

7.2 ANALYSIS OF CASE STUDIES

ECMs were selected to optimize energy efficiency across lighting, cooling, building envelope systems, etc. Each addresses specific inefficiencies in commercial buildings, contributing to overall energy savings thereby reducing carbon emission.

S. No.	Parameter	Baseline	ECM
1	WWR 40	70%	40%
2	WWR 20	40%	20%
3	Wall– 1 (W/m^2K)	2.1	0.4
4	Wall – 2 (W/m^2K)	2.1	0.7
5	Wall – 3 (W/m^2K)	2.1	1
6	SHGC-1	0.6	0.27
7	SHGC-2	0.6	0.3
8	SHGC-3	0.6	0.35
9	LPD+Control-1 (W/m^2)	1.0	0.5
10	LPD+Control-2 (W/m^2)	1.0	0.7
11	LPD+Control-3 (W/m^2)	1.0 ^{2}	0.9
12	Fan	CAV	VAV
13	COP	3.0	3.5
14	Thermostat	24°C	26°C
15	Roof SRI	0.3	0.78

Table 12 - List of Energy Conservation Measures

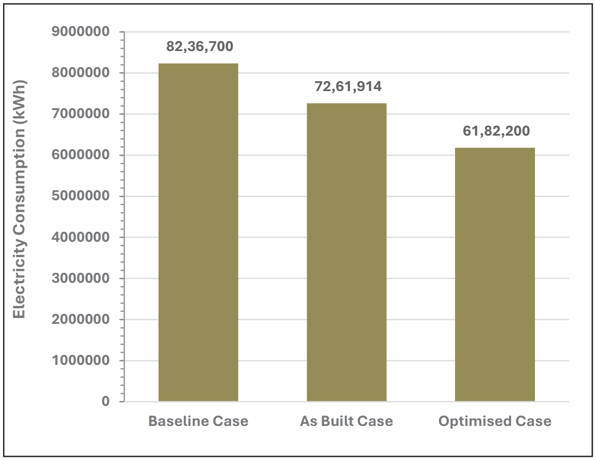


Figure 24 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

Month	Year	TR-h
JAN	2023	31,345
FEB	2023	83,749
MAR	2023	1,43,338
APR	2023	1,83,011
MAY	2023	2,80,831
JUN	2023	2,64,907
JUL	2023	2,12,370
AUG	2023	1,80,670
SEP	2023	1,83,818
OCT	2023	1,76,863
NOV	2023	1,06,183
DEC	2023	60,641

Table 13 - Cooling purchased by Pragya tower from the Gift City

	Errors	Permissible limits	Project
Monthly	MBE	±5%	-1%
	CvRMSE	15%	4%

Table 14 - Error Limits of the calibration model

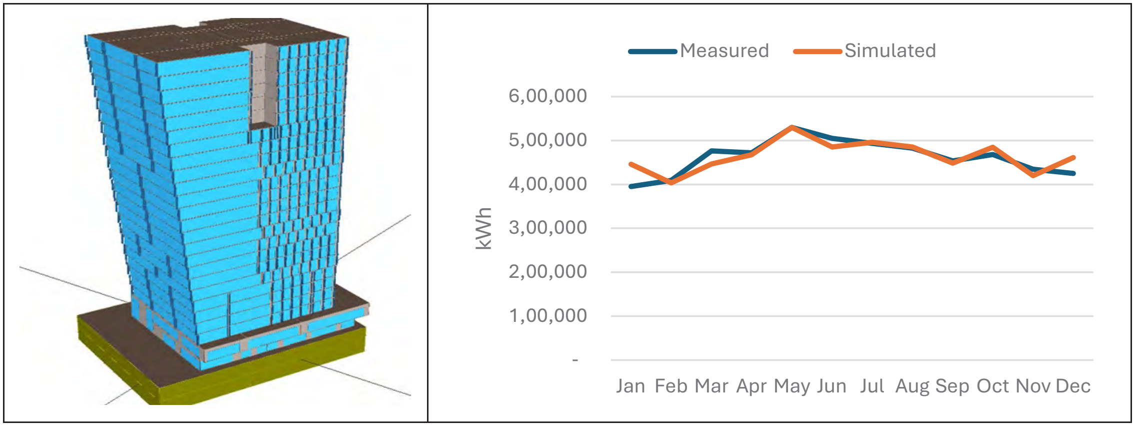


Figure 25 - 3D energy model and energy performance comparison

PRAGYA TOWER (GANDHINAGAR, GUJARAT)

Pragya Tower is located in the Gift city Gandhinagar, Gujarat. The project building is a commercial office building consists of offices (G+24 floors).The building is connected with a district cooling system managed by Gift City. Table 13 shows use of thermal energy at Pragya Tower and Table 14 represents error limits achieved and permissible thresholds.

Using measured data, calibration was performed while considering the MBE and CvRMSE for the accuracy of the calibration.

Various ECMs evaluated to reduce energy use of Pragya Tower. Key measures included optimizing WWR to 40% and 20%, SuperECBC compliant wall, and employing high SRI cool roofing. The integration of efficient glazing, EC Fan and lighting power density (LPD) along with controls further enhanced energy efficiency.

KEY ECMs

- WWR reduction (40%).
- High Performance Glazing (0.25).
- EC Fan Retrofitting.
- LPD reduction to 0.5 W/m^2 with control.

RESULTS:

Combined implementation of ECMs achieved energy savings of 25%, demonstrating the potential of bundling ECMs for maximum efficiency over baseline.

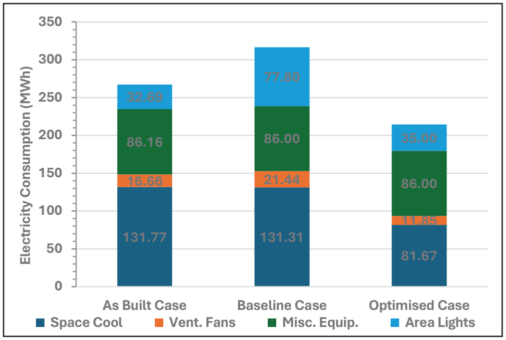


Figure 26 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

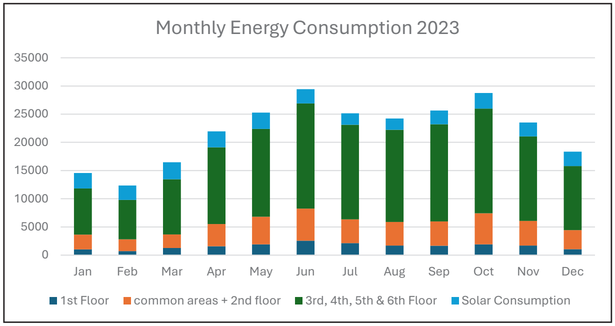


Figure 27 - Monthly energy consumption pattern of year 2023

	Errors	Permissible limits	Project
Monthly	MBE	±5%	-1%
	CvRMSE	15%	15%

Table 15 - Error Limits of the calibration model

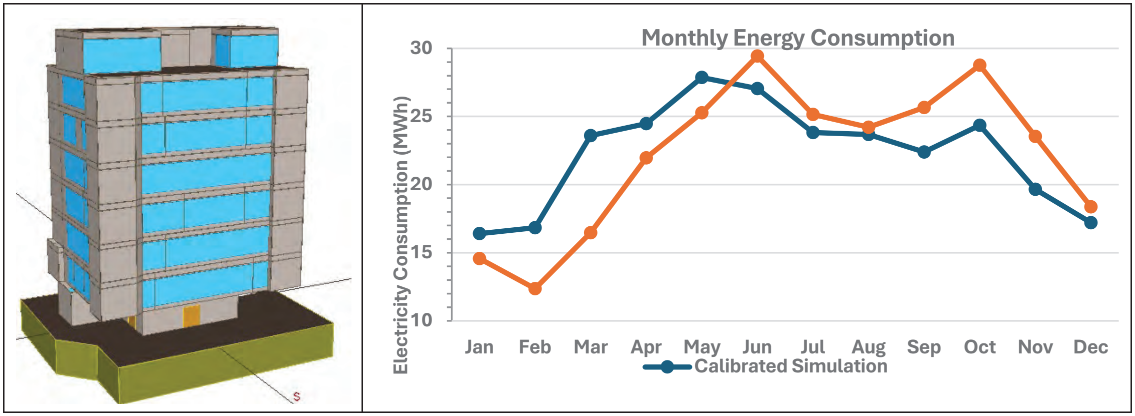


Figure 28 - 3D energy model and calibration graph

PSP HOUSE (AHMEDABAD, GUJARAT)

PSP House, a six-story office building, incorporated measures such as improved wall insulation, optimized glazing, and a high-SRI roof to enhance efficiency. Lighting and thermostat controls also played a significant role.

KEY ECMs
Super ECBC walls and glazing.
Reduced LPD with occupancy sensors.
Thermostat setpoint adjustment to 26°C.

RESULTS:

Lighting upgrades alone reduced energy consumption by 14.5%. Combined measures improved overall energy efficiency significantly.

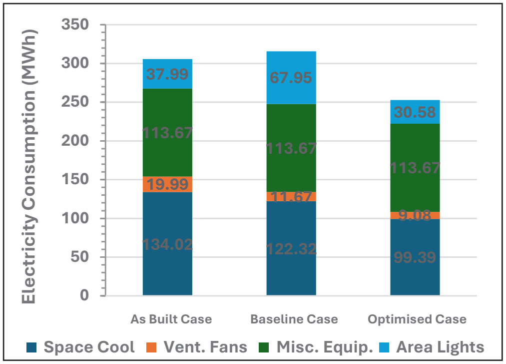


Figure 29 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

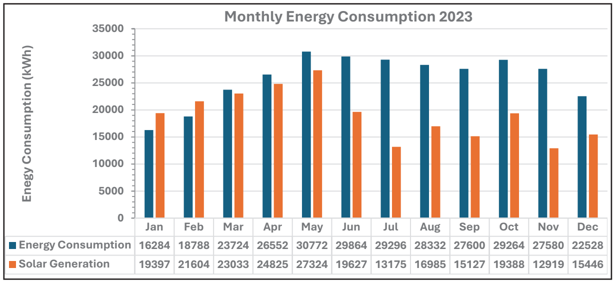


Figure 30 - Monthly energy consumption pattern of year 2023

	Errors	Permissible limits	Project
Monthly	MBE	±5%	2%
	CvRMSE	15%	11%

Table 16 - Error Limits of the calibration model

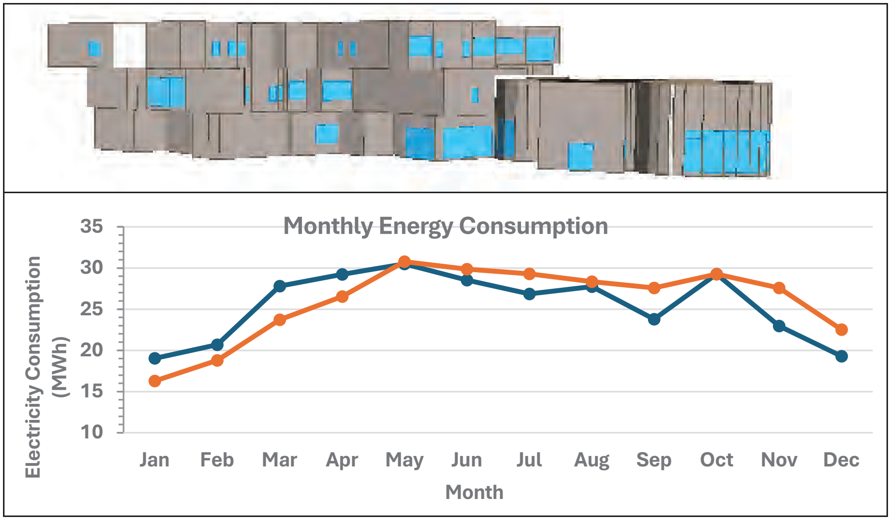


Figure 31 - 3D energy model and calibration graph

LUTHRA CORPORATE OFFICE (SURAT, GUJARAT)

This two-story corporate office leveraged VRF systems and optimized lighting through occupancy sensors. Solar PV contributed to 75% of energy needs.

KEY ECMs
High-SRI roofing and glazing upgrades.
LPD reduction with advanced lighting sensors.

RESULTS:

Approximately 2.6% savings were achieved in HVAC systems, complementing the building's solar energy reliance.

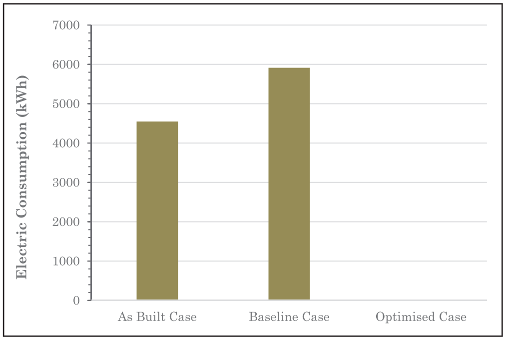


Figure 32 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

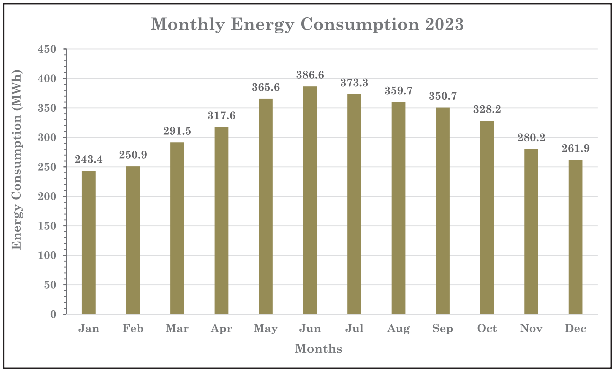


Figure 33 - Monthly energy consumption pattern of year 2023

	Errors	Permissible limits	Project
Monthly	**MBE**	±5%	-1%
	CvRMSE	15%	15%

Table 17 - Error Limits of the calibration model

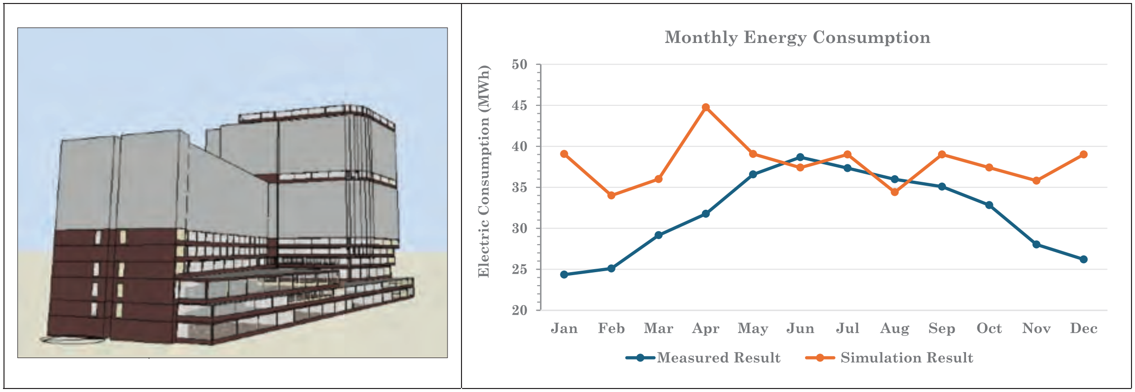


Figure 34 - 3D energy model and calibration graph

SHAPATH V (AHMEDABAD, GUJARAT)

This high-rise office building employed advanced ECMs such as reduced WWR and efficient AHU fans. The building's thermostat settings were optimized for improved comfort and efficiency.

KEY ECMs

- WWR reduction to 20%.
- Efficient AHU fans and optimized thermostat setpoints (26°C).

RESULTS:

Energy consumption was reduced by 20.44% when all ECMs were applied.

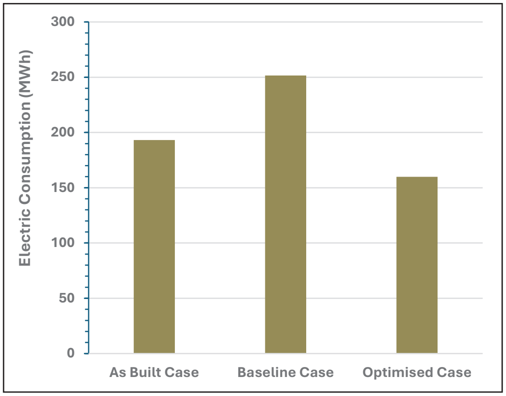


Figure 35 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

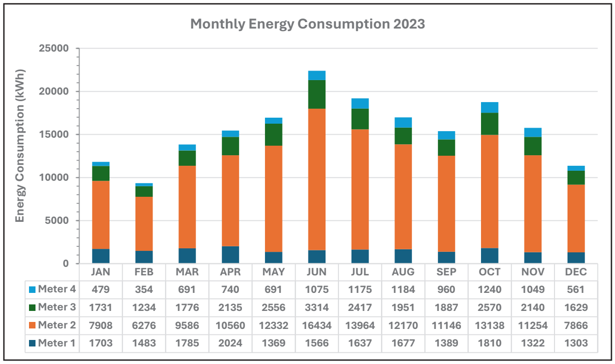


Figure 36 - Monthly energy consumption pattern of year 2023

	Errors	Permissible limits	Project
Monthly	**MBE**	±5%	-3.4%
	CvRMSE	15%	13%

Table 18 - Error Limits of the calibration model

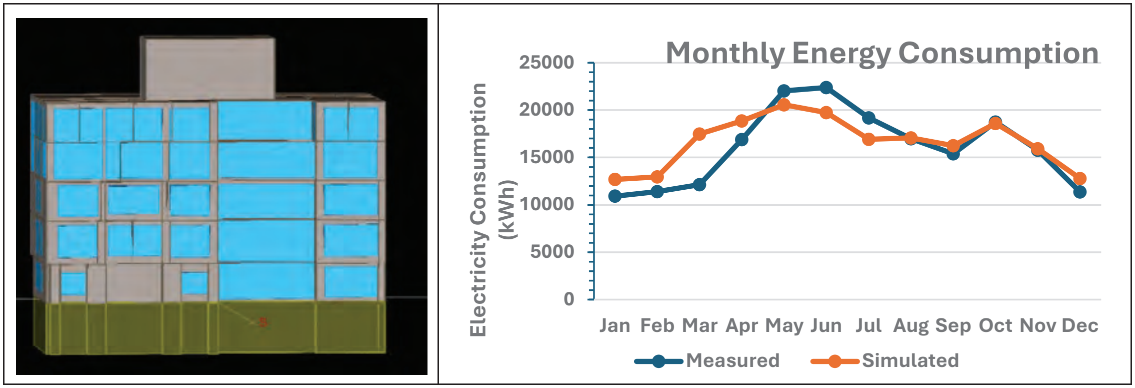


Figure 37 - 3D energy model and calibration graph

SHIVALIK HOUSE (AHMEDABAD, GUJARAT)

Shivalik House focused on glazing upgrades, WWR optimization, and lighting improvements to achieve notable savings.

KEY ECMs

- Glazing (U-value 2.2 W/m²·K, SHGC 0.25).
- Lighting optimization with occupancy sensors.

RESULTS:

Combined ECMs reduced energy consumption by approximately 12.7%.

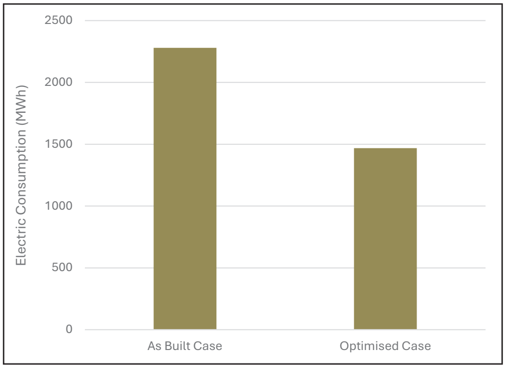


Figure 38 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

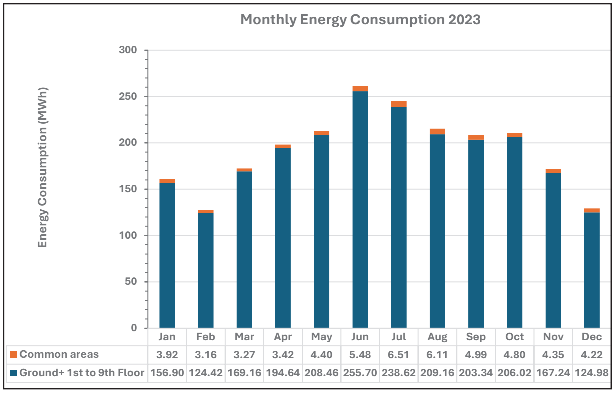


Figure 39 - Monthly energy consumption pattern of year 2023

	Errors	Permissible limits	Project
Monthly	**MBE**	±5%	0%
	CvRMSE	15%	7%

Table 19 - Error Limits of the calibration model

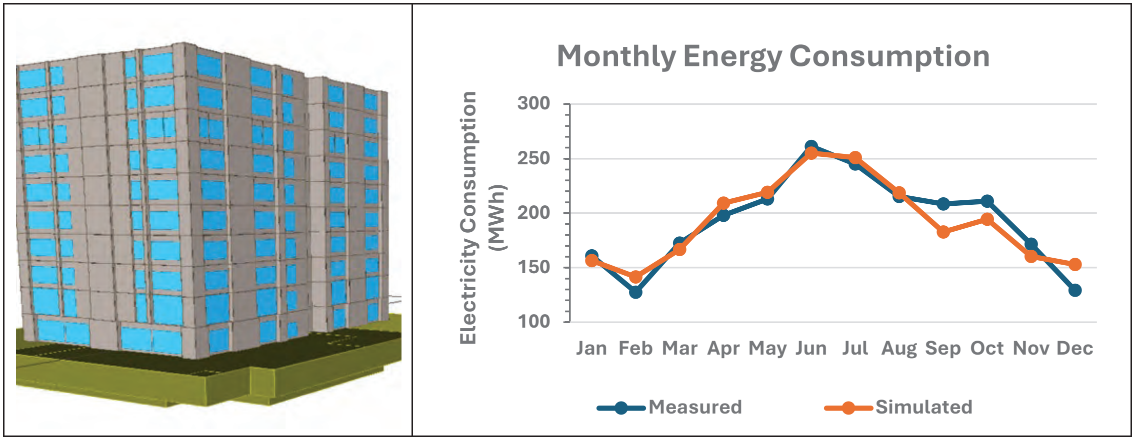


Figure 40 - 3D energy model and calibration graph

TITANIUM BUILDING - INI (AHMEDABAD, GUJARAT)

Titanium Building - INI utilized comprehensive ECMs, including glazing improvements, reduced WWR, and optimized HVAC settings.

KEY ECMs	
	Cool roofing and advanced glazing systems.
	Thermostat setpoint (26°C) and WWR reduced to 20%.

RESULTS:

Annual energy consumption was reduced by 35.6% through bundled measures.

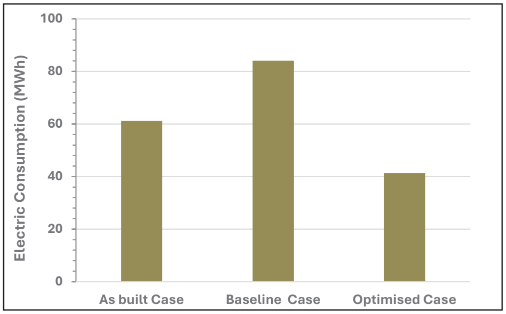


Figure 41 - Annual Energy Consumption As Built vs Baseline vs Optimised Case

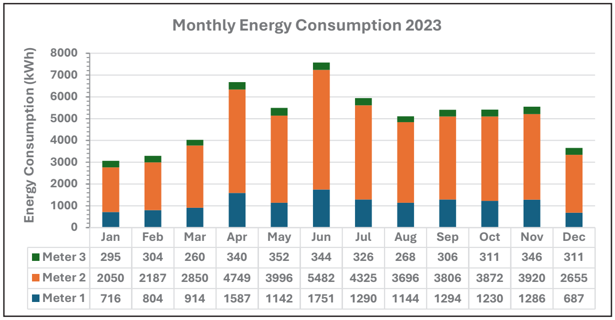


Figure 42 - Monthly energy consumption pattern of year 2023

	Errors	Permissible limits	Project
Monthly	**MBE**	±5%	1%
	CvRMSE	15%	18%

Table 20 - Error Limits of the calibration model

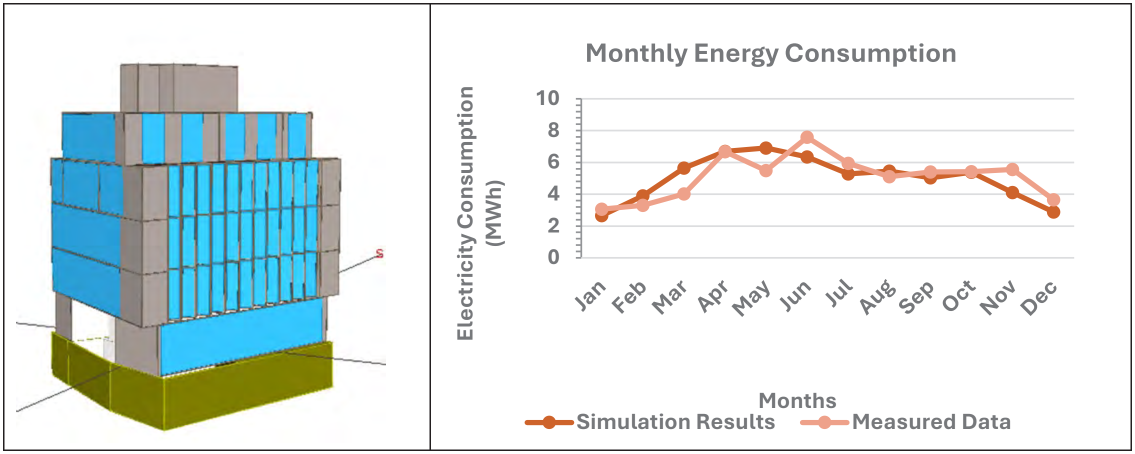


Figure 43 - 3D energy model and calibration graph

PRAKRUTI BUILDING (VADODARA, GUJARAT)

Prakruti Building utilized comprehensive ECMs, including glazing improvements, reduced WWR, and optimized HVAC settings.

KEY ECMs	
	Super ECBC walls and glazing.
	WWR reduction to 20%.

RESULTS:

Annual energy consumption was reduced by 50.9% through bundled measures.

7.3 PARAMETRIC ANALYSIS OF ECMS

Energy Conservation Measures (ECMs) play an important role in reducing energy consumption and to achieve Net Zero Energy/Carbon status. This section evaluates the energy saving potential through identified list of ECMs. This analysis provides actionable insights for decision makers aiming to optimize energy efficiency in buildings.

As previously mentioned, a base case is developed to serve as a reference to estimate energy savings potential of each ECM. It is noted that, the reference case developed considering various parameters including building envelope, HVAC systems, lighting, and occupancy patterns etc. of the selected case studies. This reference case is used to determine specific energy savings by

S. No.	Parameter	Baseline	ECM	Energy Saving potential (kWh/m^2/year)	Cost Savings (Rs/sq.m-yr)
1	WWR - 1	70%	40%	10.3	103
2	WWR - 2	70%	20%	14.8	148
3	Wall-1 (W/m^{2}K)	2.1	0.4	4.2	42
4	Wall-2 (W/m^{2}K)	2.1	0.7	3.7	37
5	Wall-3 (W/m^{2}K)	2.1	1	1.8	18
6	Roof SRI*	0.3	0.78	15.9	159
7	SHGC -1	0.6	0.27	14.6	146
8	SHGC -2	0.6	0.3	10.4	104
9	SHGC -3	0.6	0.35	7.2	72
10	LPD+controls-1 (W/m^2)	1.0	0.5	12.7	127
11	LPD+controls-2 (W/m^2)	1.0	0.7	7.4	74
12	LPD+controls-3 (W/m^2)	1.0	0.9	4.1	41
13	Fan	CAV	VAV	8.6	86
14	COP	3.0	3.5	9.6	96
15	Thermostat	24°C	26oC	6	60

Table 21 - Energy saving potential of different ECMs

**Energy/cost savings in case of SRI paint (cool roof) is calculated only for the top floor area.*

each ECM. The results provide a comparative understanding of energy savings potential, helping in the identification of the most effective measures for improving building energy efficiency. Table 21 and Figure 44 highlight specific energy saving potential (kWh/m²) of each ECM.

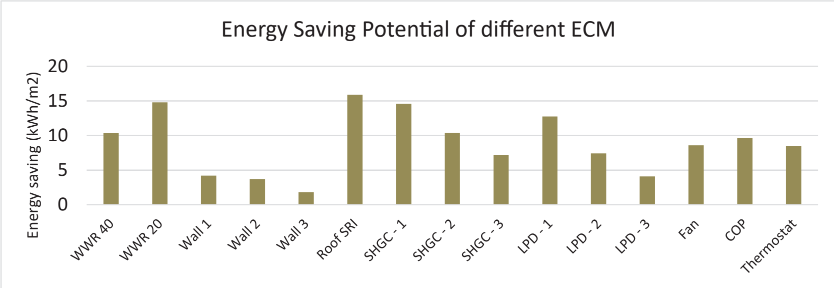


Figure 44 - Graphical representation of energy saving potential of different ECMs

1. Window-to-Wall Ratio (WWR):

The study shows that the reduction in WWR offers the highest energy savings (14.8 kWh/m²/year). Reducing WWR from 70% to 20% reduced cooling loads up to 15% and optimal WWR balances daylighting benefits with thermal performance.

2. SHGC (Solar Heat Gain Coefficient):

Lowering SHGC to 0.27 also results in high savings of 14.6 kWh/m²/year. Adding wall insulation (Wall-1: 2.1 to 0.4 W/m²K) saves 4.2 kWh/m²/year.

3. Lighting Upgrades:

Lower LED reduces energy use by 10-14% and decreases heat emissions, minimizing HVAC cooling requirements, leading to cost effective HVAC downsizing and improved thermal comfort.

4. Cool Roof:

High SRI materials reduce solar heat gain, lowering roof temperatures and HVAC cooling loads. This measure is cost-effective for retrofits and essential for new constructions in hot climates. Cool roof is more effective in case of large footprint of buildings having more roof areas.

5. HVAC Systems:

Retrofitting/ replacing HVAC system by higher performance offers more savings. High-efficiency HVAC systems and optimised thermostat led 10-15% energy savings. Thermostat setpoint upto 26°C has more savings and creates the environment thermally more comfortable (saves upto 9% of energy used).

6. Retrofit of Building Envelope:

Altering wall materials and window glasses can significantly impact the heat gain from the building envelope. Building envelope (WWR, Wall, and Glass) has potential to save energy over 32 kWh/sqm-yr considering code compliances.

7.4 FINANCIAL ANALYSIS OF ECMS

This section presents the financial implications of various ECMs. By aligning costs with energy savings, stakeholders can make informed investment decisions. For example, change in thermostat delivers immediate returns with no investment, while glazing and cool roofs offer medium term paybacks with high energy savings potential.

Financial analysis includes estimating the total cost of implementation of each ECM which includes the cost of material, labour, installation expenses etc. Subsequently, electricity cost savings per year is estimated based on the reduction observed in energy consumption. Then, payback period is determined by comparing the initial investment cost with the annual cost savings. This helps stakeholders prioritize ECMs based on their Return on Investment (ROI), ensuring optimal energy efficiency in building operations.

7.4.1 Assumptions

The financial analysis relies on standardized cost assumptions for materials, labour, and preparatory work. These assumptions provide a consistent basis for evaluating the economic feasibility of ECMs. The cost assumptions used in the analysis are presented in the Table 22.

ECM Type	Cost Parameters	Cost Assumption (₹/unit)
Wall material	Material Cost	₹700/sq.m
	Labour Cost for Installation	₹100/sq.m
Glazing Improvements	Basic Glazing Cost	₹800/sq.m
	High-Performance Glazing Cost	₹1,200/sq.m
	Labour Cost	₹400/sq.m
Roof SRI Coating	Coating Material	₹200/sq.m
	Installation and Preparation Cost	₹100/sq.m
WWR Reduction	Cost for Reductions	₹500/sq.m
LPD+Control	Sensor Equipment Cost	₹380/sq.m
	Installation Cost	₹20/sq.m
Fans	Cost of efficient Fan	₹200/sq.m
COP	Cost of efficient system	₹10,000/TR

Table 22 - Cost assumptions considered in the financial assessment

7.4.2 Payback Period analysis:

The analysis shows varying payback periods for different ECMs. This subsection provides a clear understanding of cost benefits of each measure.

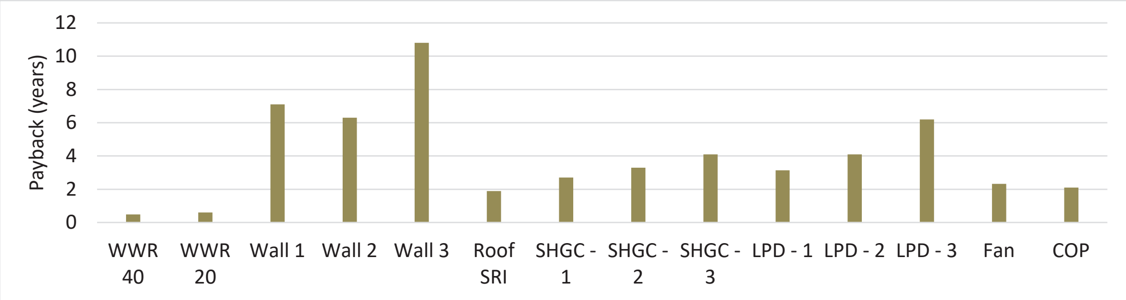


Figure 45 - Payback period of different ECMs

S. No.	Parameter	Payback Period (Years)	Payback Time (Years)
1	WWR 40	10.3	0.5
2	WWR 20	14.8	0.6
3	Wall 1	4.2	7.1
4	Wall 2	3.7	6.3
5	Wall 3	1.8	10.8
6	Roof SRI	15.9	1.9
7	SHGC - 1	14.6	2.7
8	SHGC - 2	10.4	3.3
9	SHGC - 3	7.2	4.1
10	LPD - 1	12.7	3.1
11	LPD - 2	7.4	4.1
12	LPD - 3	4.1	6.2
13	Fan	8.6	2.3
14	COP	9.6	2.1
15	Thermostat	8.5	0.0
16	Overall ECM	74	2

Table 23 - Payback period of different ECMs analysed

7.5 SUMMARY

This section synthesizes the findings from the parametric analysis, highlighting the energy savings achieved in Green (New Construction) and Brown field (Existing) building projects in Gujarat.

7.5.1 Greenfield (New Construction) Projects

For new buildings, the primary focus is on incorporating energy-efficient design elements from the outset to maximize long-term energy savings. These ECMs are cost-effective when integrated into the initial design and construction process.

Key Findings for Green Field Projects

Optimized Window to Wall Ratio (WWR)	• **Maintaining WWR at** 40% **results i**n significant energy savings (10.3 kWh/m^2) and it also offers good **daylight.** • **Reducing WWR to** 20% **provides more savings (14.8 kWh/m^2),** however **may impact daylight availability.**
SHGC	• SHGC of 0.27 achieves the highest savings (14.6 kWh/m^2) by reducing unwanted solar heat gain. • SHGC values of 0.30 and 0.35 offer moderate savings (10.4 kWh/m^2 and 7.2 kWh/m^2, respectively). • Selection of SHGC should be climate-specific to balance daylight and cooling loads.
Building Envelope (Wall & Roof)	• Wall with U-values of 0.4 - 0.7 W/m^2K helps reduce heat transfer, with savings between 3.6 and 4.2 kWh/m^2. • Roof Solar Reflectance Index (SRI) contributes marginally (0.8 kWh/m^2) and it mitigates Urban Heat Island (UHI) effect.
Lighting System	• Lighting Power Density (LPD) of 0.5 results in 12.7 kWh/m^2 of savings. • LPD between 0.7 & 0.9 achieve 7.4 kWh/m^2 and 4.1 kWh/m^2, respectively.
HVAC System	• System COP improve savings, 9.6 kWh/m^2. • EC/Axial Fan improve HVAC efficiency, can save 8.6 kWh/m^2. • Higher Thermostat (26oC) saves 8.5 kWh/m^2. This is easy to implement with no initial cost/investment.

Suggested ECMs for New Construction

ECM	Energy Savings (kWh/m^2)	Payback	Implementation Priority
Higher Thermostat	8.5	High	High Priority
SHGC (0.27)	14.6	Moderate	
LPD (0.5 W/m^2)	12.7	High	
WWR (20%)	14.8	High	
Higher COP HVAC	9.6	Moderate	Medium Priority
EC/Axial Fan	8.6	High	
Wall U-value (0.4-0.7 $W/m^2.K$)	3.6 – 4.2	Moderate	Low Priority
High SRI Roof	0.8	Low	

Table 24 - Energy Savings Potential of ECMs - New Construction

7.5.2 Retrofitting of Existing Buildings

For existing buildings, the priority is to implement ECMs that offer high energy savings with shorter payback periods to ensure financial viability.

Suggested ECMs for Retrofitting

ECM	Energy Savings (kWh/m^2)	Payback	Implementation Priority
Higher Thermostat	8.5	High	High Priority
SHGC (0.27)	14.6	Moderate	
LPD (0.5 W/m^2)	12.7	High	
Higher COP HVAC system	9.6	Moderate	Medium Priority
EC/Axial Fan	8.6	High	
Wall Insulation	3.6–4.2	Moderate	Low Priority
High SRI/Cool Roofs	0.8	Low	

Table 25 - Energy savings potential of ECMs - Existing Buildings

Key Findings for Building System/Equipment Retrofitting

Retrofitting of Lighting systems	• Lower LPD (0.5 W/m^2) saves 12.7 kWh/m^2, offering significant returns with short payback periods. • Install efficient LED lighting fixtures with high efficacy (>120 lum/W).
HVAC System	• EC/Axial fans improve efficiency and contribute to 8.6 kWh/m^2 of energy reduction. • Higher thermostat offers energy savings, 8.5 kWh/m^2. • Any HVAC system which is older than 15 years (or consider operational performance through energy audits) shall be retrofitted with higher COP systems which can save 9.6 kWh/m^2.
SHGC	• Reducing SHGC to 0.27 provides 14.6 kWh/m^2 of savings, it can be either by glass treatment or glass films or through shading devices. • SHGC values of 0.30 and 0.35 offer slightly lower savings however still reduce cooling loads.
Building Envelope	• Cool Roof (High SRI roof) results energy savings equivalent to 0.8 kWh/m^2 and also improves thermal comfort, and eliminate/reduce UHI effect.

RECOMMENDATIONS

8.1 LOW EMBODIED CARBON BUILDINGS

The study has observed embodied carbon footprint in the range of 490 – 613 kgCO_2e/sq.m excluding interior materials. Therefore, it is recommended to set target for achieving maximum embodied carbon emission to 550 kgCO_2e/sq.m for high rise buildings and to keep maximum carbon footprint of 500 kgCO_2e/sq.m for mid-rise buildings, as shown in Figure 46.

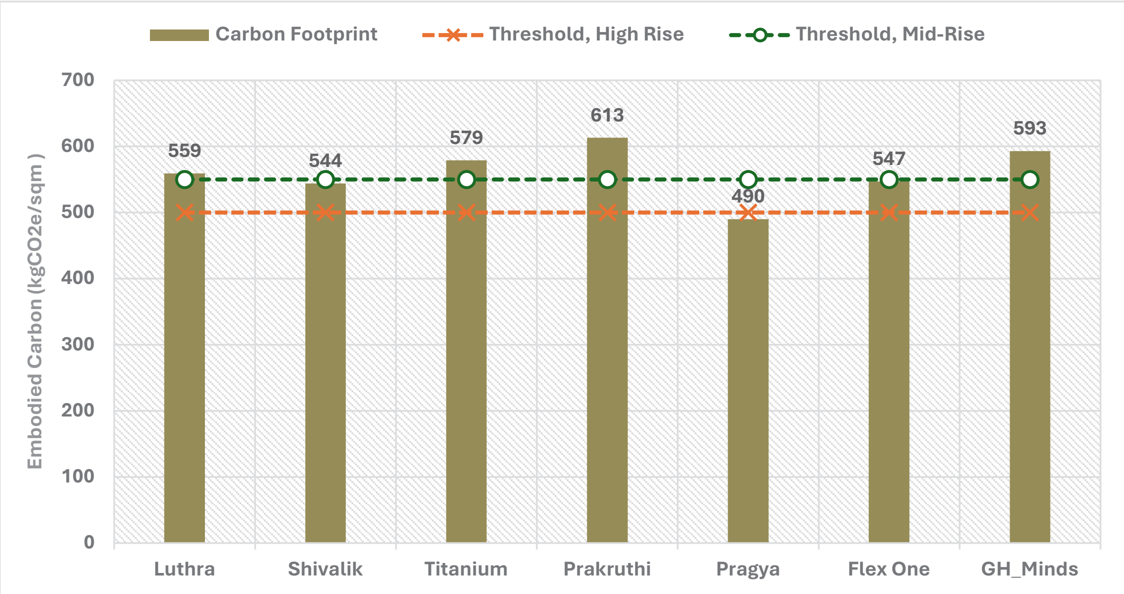


Figure 46 - Embodied Carbon of case study partners

The study recommends end users, developers, builders, PMCs, etc. to maintain a detailed Bill of Quantify (BOQ) from the design stage, this enables projects to explore options to identify products with low carbon footprint.

The recommendations for overall reduction in the embodied carbon footprint of the buildings including structural and non-structural element are as follows:

Structural components:

• **Certified Products**

Projects to use GreenPro (Eco-labelled) or equivalent certified products to reduce embodied carbon emission.

• **Low Embodied Carbon Steel**

Avoid over designing structural elements and use steel with low embodied carbon to optimize material usage. Steel TMT with recycled content (Secondary Steel) has 40-60% low embodied carbon when compared with primary steel.

• **Cement with alternative cementitious material**

Use cement with reduced clinker usage. Flyash based cement has 20-25% less embodied carbon compare to Ordinary Portland Cement (OPC). Similarly, slag-based cement has 35-40% less embodied carbon than OPC.

• **Reduce Vertical Precast Element (Walls)**

Precast concrete slabs reduce the quantum of concrete requirement, thus reducing the overall embodied carbon of a building. However, vertical precast elements like walls, apart from shear walls, will increase the overall embodied carbon of the building.

• **Promote High Performance Glass**

Though the embodied carbon of high performance DGU glass is higher when compared to a single glazed unit, operational carbon is low (20-30% in high-rise buildings). In case of low-rise buildings, 10-15% reductions in operational carbon can be achieved by using a combination of low U-value and low emissivity glasses.

• **Use of Terracotta Claddings and other rain screen systems**

Terracotta claddings have very low embodied carbon compared to other composite claddings, aluminium claddings. This reduces the overall contribution from façade to embodied carbon.

• **Use of Composite cladding systems and Louvers in high-rise buildings**

Usage of composite cladding systems also reduce the overall weight of the façade elements thus decreasing the embodied carbon. The Table 26 summarises various strategies to implement low carbon building materials to reduce embodied carbon.

Component	Contribution to overall Embodied Carbon	Strategies	Implementation Priority	Cost Difference per kg for low embodied carbon material
Steel TMT Rebar	30% - 45%	Use Low Embodied Carbon Steel (Secondary Steel)	High	Rs. 2-4
Cement	30% - 45%	Promote Alternative Cementitious Materials	High	Rs. 1-3
Vertical Precast Walls	5%-10%	Reduce Vertical Precast Elements (Walls)	Medium	NA
Exterior Glass in Facade	5%-7%	High-rise: Use High Performance Glass (DGU). Low & Mid Rise: Combination of low U-Value & low emissivity glass of single glazed unit	High	NA

Table 26 - Embodied Carbon of different materials – Structural Element

Non-structural components:

• **Promote use of construction blocks/paver blocks with alternate materials**

For partition walls/non-structural walls, construction blocks with alternative materials like fly ash, C&D waste can be utilised. External paver blocks made with post-consumer plastic waste and post-industrial plastic waste need to be used as their embodied carbon is almost close to nil for 80%-90% recycled content.

• **Adopt water based Single Coat paints**

Water-based paints inherently have low VOC levels and offer a 25–30% higher spread rate compared to conventional solvent-based paints. Additionally, the use of single-coat water-based interior emulsion reduces the total paint quantity by a further 15–20%. As a result, the embodied carbon contribution from interior paints alone is reduced by approximately 50%.

• **Carpet, Boards and Panels:**

Standard nylon-backed carpets have an embodied carbon footprint in the range of 7–10 $kgCO_2e/m^2$, depending on thickness. From a whole-building perspective, carpet flooring contributes approximately 5–6% of the total embodied carbon. Therefore, minimizing carpet use in areas without specific functional requirements is advisable. Where carpets are necessary, options containing 25–80% recycled nylon fibers should be prioritized to reduce carbon impact.

Similarly, promoting the use of boards and panels made from alternative, recycled, or rapidly renewable materials can further reduce embodied carbon. For partitions or acoustic applications, materials incorporating post-consumer or post-agricultural waste—such as sugarcane bagasse, rice husk ash, or sawdust—can be effective. When wood-based products are required, sourcing from Forest Stewardship Council (FSC)-certified suppliers is recommended.

Table 33 outlines key strategies to reduce embodied carbon in non-structural building elements.

Component	Contribution to overall Embodied Carbon	Strategies	Implementation Priority
Construction & Paver Blocks	4 to 9%	Use of blocks and paver blocks with industrial waste, agricultural waste, C&D waste.	High
Plastering	1 to 3%	Promote use of Ready Mix Plaster Reduce Special Architectural Plastering	High
Paints	0.5 to 2%	Adopt water-based single coat paints	High
Carpets	5 to 7%	Use carpets with recycled fibre content / prefer vitrified tiles.	Medium
Boards & Panels	1 to 2%	Use boards with post-consumer/ agricultural waste	High

Table 27 - Embodied Carbon of different materials – Non-structural Element

8.2 LOW OPERATIONAL CARBON BUILDINGS

In commercial buildings, selection of Energy Conservation Measures (ECMs) shall be based business economics considering financial analysis and energy saving potential.

Strategies to reduce Operational Carbon Emission in New Construction:

- A 40% WWR balances energy savings (10.3 kWh/m²) and daylight.
- Solar Heat Gain Coefficient (SHGC): SHGC of 0.27 gives the highest energy savings (14.6 kWh/m²).
- Walls with U-value between 0.4–0.7 W/m²K save up to 4.2 kWh/m², it is important to use code compliant roof along with reflective coating (SRI more than 78%) to mitigate Urban Heat Island (UHI) effect.
- Lower Lighting Power Density (LPD) of 0.5 offers high savings (12.7 kWh/m²).
- Improvements in COP, energy-efficient fans (axial/EC), and thermostat setting (26°C) can save 8.5–9.6 kWh/m².

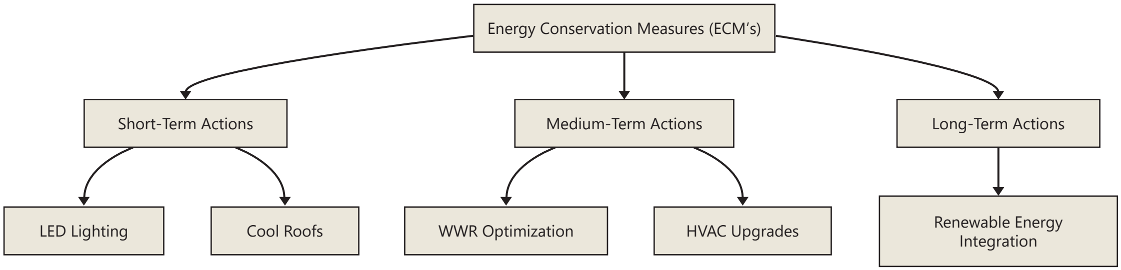


Figure 47 - Strategies for reducing Operational Carbon in New Construction

Strategies to reduce Operational Carbon Emission in Existing Buildings:

- Lighting Systems: Reducing LPD to 0.5 W/m² saves 12.7 kWh/m² with use of high-efficacy LED fixtures (>120 lumens/Watt) for better performance.
- HVAC Systems: EC/Axial fans enhance efficiency, saving 8.6 kWh/m², keeping higher thermostat (26°C) saves 8.5 kWh/m². it is suggested to retrofit HVAC systems older than 15 years or inefficient units to high-COP systems to achieve higher savins, 9.6 kWh/m².

- SHGC Optimization: It is not possible to resize WWR in existing buildings however considering glass shading devices, glass treatment, glass film can reduce SHGC significantly (SHGC to 0.27 can save 14.6 kWh/m^2). SHGC values between 0.30 and 0.35 still offer good savings and reduce cooling loads.
- High Solar Reflectance Index (SRI) roofs save 15.9 kWh/m^2 (top floor area only), enhance thermal comfort, and reduce Urban Heat Island (UHI) effect.

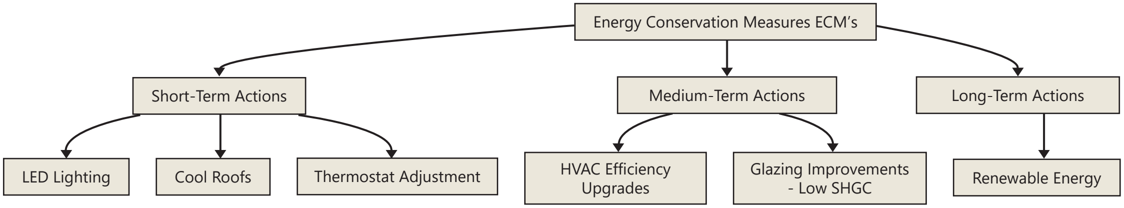


Figure 48 - Strategies for reducing Operational Carbon in Existing Buildings

8.3 RECOMMENDATIONS TO ACCELERATE NET ZERO CARBON (COMMERCIAL BUILDINGS)

Energy Efficiency Standards and Electricity Usage	• New commercial building spaces to comply with ECBC 2017 (achieving mini. efficiency) or ECSBC 2025. • Commercial building more than 1,000 sq.m or 100 kW load to comply with the ECBC 2017/ECSBC especially the HVAC equipment. • Mandatory retrofitting of existing buildings as provided under section **8.2 above (Low Operational Carbon Buildings).** • Projects with DHW (Domestic Hot Water) to install Heat Pump. • To achieve carbon neutrality, Government to enforce policies allowing building to interact with the grid and use renewable energy regardless of any restrictions.
Low-Carbon Building Materials and Equipment	• Eco-labelled (Green Materials), use of steel, cement following Annexure-1 and considering low carbon building materials can reduce carbon intensity or carbon footprint per sq.m of the construction (achieving carbon footprint, 500-550 kgCO_2e/m^2-yr).

Low-Carbon Building Materials and Equipment

- Implement organizational policy to procure energy efficient and low-carbon building materials and equipment such as recycled steel, low-carbon concrete, low carbon air-conditioners, sustainably timber, etc. At least 50% by cost, building materials to be low embodied carbon in all commercial buildings.
- Govt to roll out financial incentive policy (e.g. reduced energy tariff, auto renewal of Consent to Operate – CTO by State Pollution Control Board or based on green factory certification, provide incentives, percentage reduction in Consent to Operate – CTO fee, etc.) following green certification level to manufacturers producing green/low-carbon materials.

Continue Performance Monitoring and Reporting

- Establish a robust monitoring system to track energy/carbon emissions and achieve industry benchmarks.
- Govt to recognise building owners/stakeholders for achieving energy/ carbon thresholds (e.g. RECA Awards conducted by Govt of Rajasthan).
- Building projects to integrate AI and digital twin solutions to explore best performing ECMs and realise real time performance.

Financial Incentives

- Offer tax credits or subsidies for buildings that achieve high energy efficiency (40% savings over baseline or EPI<50-60 kWh/m^2-yr) or carbon footprints (500-550 $kgCO_2e$/sq.m).
- Create green financing options to support investments in energy-efficient and low-carbon technologies (e.g. through ESCOs, Energy Service Companies or financial institutions to provide subsidised loans to support retrofitting).
- Govt to offer reduced electricity tariff by Rs. 0.5/kWh to meet RE target 30-50% by 2030 or EPI lower than <50 kWh/m^2-yr when AC area is more than 50%.
- Reduce property tax by 10-15% for Green Buildings, more than 20% for Net Zero Energy and 30% for Net Zero Carbon buildings.

Capacity building and outreach

- Capacity building programs for stakeholders (Developers, Architects, MEP Consultants, Engg Professionals etc.) to explore code compliances, NZE and NZC.
- Gujarat Renewable Energy Development Agency (GEDA) to launch Training on Net Zero Energy & Carbon for Commercial Buildings.

STUDY FINDINGS AND ESTIMATED GROWTH IN THE BUILDING SECTOR

9.1 STUDY IMPACT AND SAVING POTENTIAL

Gujarat's building sector is thriving, driven by strong economic growth, large-scale infrastructure projects, and a booming real estate market—particularly in cities like Ahmedabad, Surat, and Vadodara. The state's policy-driven environment and focus on infrastructure have attracted significant foreign direct investment (FDI), further accelerating development.

Commercial buildings account for a major share of Gujarat's energy use, especially due to high dependence on air-conditioning systems in its two dominant climatic zones—Hot & Dry and Warm & Humid. This reliance contributes substantially to carbon emissions.

Studies show that high ambient temperatures—often exceeding 40°C—lead to heavy use of cooling systems. While agencies like The Bureau of Energy Efficiency (BEE) and Gujarat Energy Development Agency (GEDA) have promoted energy efficiency through policies such as the Energy Conservation Building Code (ECBC), adoption of Energy Conservation Measures (ECMs) remains limited due to low awareness, upfront investment concerns, and policy gaps.

This study evaluated ECMs across selected case studies and recommends their implementation to reduce both energy use and carbon emissions. The estimated investment for ECMs is around ₹2,000/sq.m (including materials, labour, and installation). Despite the initial cost, efficiency gains result in a short payback period of 2–3 years. On average, ECMs deliver annual energy savings of 74 kWh/sq.m. Considering Gujarat's total commercial building stock of 55 million sq.m, the potential cumulative annual energy savings from statewide ECM adoption can be calculated as follows:

Total annual energy savings, 74 (kWh/sq.m)* 55 Million (BUA) = 4,070 Million kWh

9.2 STUDY IMPACT, ESTIMATED GROWTH AND REDUCTION IN CARBON FOOTPRINT

This report estimates of the number of commercial buildings and total built-up area in Gujarat for the years 2023 and 2030. The projections draw on real estate trends, government reports, energy use forecasts, and population growth patterns. These estimates serve as a foundation for assessing embodied carbon emissions in the state's commercial building sector. By 2030, the estimated embodied carbon emission would be between 45-63 MtCO2e. Hence, there is a need to reduce the carbon footprint - embodied and operational by implementing the measures suggested by the study.

Year	Estimated Number of Commercial Buildings	Estimated Built-up Area (Million sq.m)	Embodied Carbon Estimate ($MtCO_2e$)
2023	22,000 – 25,000	55	27.5 – 38.5
2030	35,000 – 40,000	90	45 – 63

Table 28 - Estimated Commercial Building Stock in Gujarat

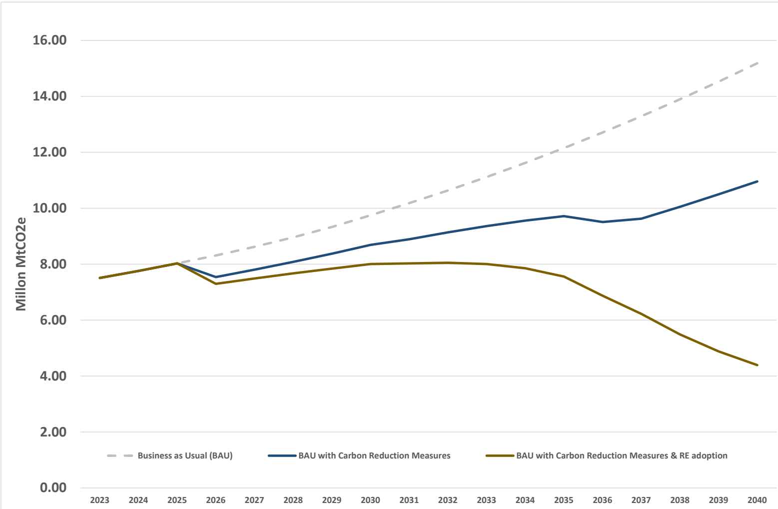


Figure 49 - Imapct of the Study

ROADMAP FOR GUJARAT STATE TOWARDS CARBON NEUTRALITY

The study recommends the following measures for achieving Net Zero energy and Net Zero Carbon Performance of Green Field and Existing Building projects in Gujarat.

Policy & Regulation	• The State Government to propose policy & regulation mandating ECBC 2017/ECSBC for all new commercial buildings and launch a Green Retrofit Policy (or Existing Building to meet IGBC Green Existing Building Certification compliance) those are >10 years old. • Incentivize use of low-carbon materials (eco-labelled cement, steel, etc.) and mandate green procurement policy (similar to other State PWDs).
Technical Implementation	• Retrofit existing HVAC systems with EC/axial fans, energy-efficient motors and enforce LED retrofits in commercial spaces, to achieve LPD 0.5 W/sq.ft. • Projects to install shading devices whenever WWR is over 40% and deploy rooftop solar PV and encourage off-site renewable PPAs.
Targets	• Retrofit 20% of existing commercial stock (11 million sq.m) to save 370 million kWh/year savings. • Reduce operational carbon by 40% and reach 50% carbon savings by achieving near net zero energy targets by 2030. • Avoid 8–10 $MtCO_2e$ embodied carbon via low-carbon construction.
Full-scale ECM Adoption by 2030	• All buildings >1,000 sq.m or >100 kW contract demand to under-go audits every 3 years, to identify gaps and implement measures. • Enforce mandatory thermostat & chilled water temperature controls and mandate net-zero-ready design for all new constructions post 2035.
Financial incentives	• Set up green financing schemes based on building energy and carbon performance. Majorly, existing projects to be financed to realise savings.

Through these endeavours commercial buildings in Gujarat can reach Net Zero Energy & Carbon Status, in line with the National commitment.

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ANNEXURE-I

The following list of low carbon materials are compiled based on the products those are available in the market with proper embodied carbon numbers.

Product	Embodied Carbon (GWP)	Remarks
Structural Elements		
Primary Steel	2,350 kg CO_2 eq/MT	
Secondary Steel	850 kg CO_2 eq/MT	99% Recycled Content
PPC (Fly ash Based cement)	598 kg CO_2 eq/MT	50% Fly ash Content
PSC (Slag Based cement)	325 kg CO_2 eq/MT	70% slag content
Glass		
4 mm glass	6 kg CO_2 eq/kg	64% recycled Content
Tiles, Paver Blocks and Construction Blocks		
Tiles	0.273 kg CO_2 eq/kg	Made of recovered carbon black
Paver Block	0.4 kg CO_2 eq/kg	30% Post consumer mixed plastic waste and 70% waste foundry sand.
Fly Ash Brick	0.142 kg CO_2 eq/kg	70% fly ash content 600mm x 200mm x 75 mm
Interiors		
Architectural Profiles	3.245 kg CO_2 eq/kg	Made from Bamboo Cullets, Recycled HDPE and Saw Dust
Boards	2.38 kg CO_2 eq/kg	30% Rice Husk Ash and 21% Recycled HDPE
Panels	0.59 kg CO_2 eq/kg	90% post agricultural waste.
Paint	1.31 kg CO_2 eq/lit	Single Coat Interior Emulsion
Carpet	0.543 kg CO_2 eq/sqm	Made with bio resins, biofillers, 25% post-consumer recycled nylon.

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