GODREJ
DESIGN
LAB

CONSCIOUS TRENDS
REPORT 2024

Building a **Climate Conscious** India

Scalable solutions for a low-carbon built environment

CEEW
THE COUNCIL

Integrative Design Solutions

Foreword

Building a Climate Conscious India

Scalable solutions for a low-carbon built environment

Dr. Arunabha Ghosh

Founder-CEO, Council on Energy, Envoironment and Water (CEEW)

As the centrepiece of global climate policy, decarbonisation is a crucial strategy to limit the Earth's rising temperatures to 1.5 – 2°C. The built environment holds the potential to solve about a third of the decarbonisation puzzle. Yet, it is a highly intricate ecosystem, encompassing a diverse array of stakeholders, from builders, architects, and project consultants to policymakers, construction companies, and consumers. Success in this domain can propel us significantly closer to a net-zero reality, creating green supply chains and generating sustainable livelihoods along the way.

Reducing emissions in the building sector has long been a focus of policy discussions. However, challenges persist across urban planning, project design, supply chains, and policy implementation. To achieve impact at scale, a systemic transformation is imperative – one where all stakeholders align towards shared goals. This necessitates consensus on the high-impact interventions the sector must prioritise and the solutions that merit significant business innovation and financial support.

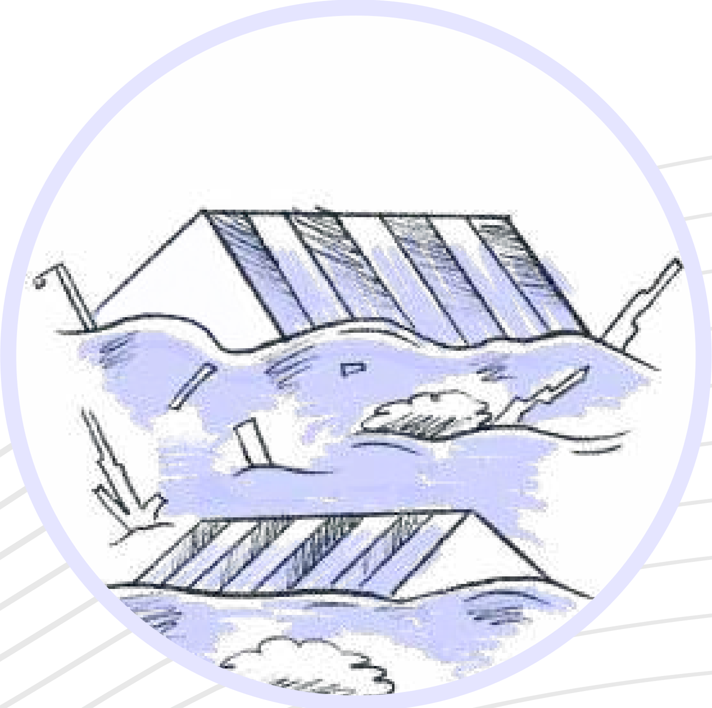
The report *Building a Climate-Conscious India: Scalable solutions for a low-carbon built environment* provides a timely trend analysis, spotlighting solutions with the potential to drive commercial development, investment, and widespread adoption. As time runs out, the emphasis must shift from isolated pilot successes to models that deliver impact at scale. Achieving this requires the right mix of cost-efficiency, skills development, and alignment with consumer preferences. Encouragingly, the market is showing readiness to embrace low-carbon interventions. The next step is to empower key actors and unlock the levers that will transform this opportunity into a win for both business and the climate.

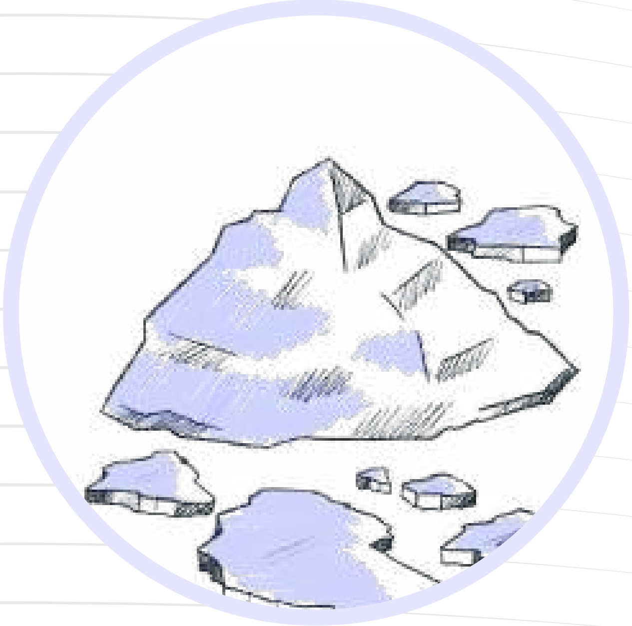
The case studies presented in this report underscore the lessons and inspiration we can draw from small-scale successes. By pivoting focus toward action, adoption, and scalability, the built environment can take bold strides toward a low-carbon future. Together, we have the opportunity to catalyse this transformation and create a lasting impact.

Table of Contents

Executive Summary

Climate change is one of the biggest challenges for human survival. Rising heatwaves, erratic monsoons, increased cyclonic activity are telltale signs of the impact of climate change, leading to loss of life, livelihoods, and economic activity. Countries around the world incur huge bills every year in the form of loss and damage due to climate change induced extreme weather events (EWE).



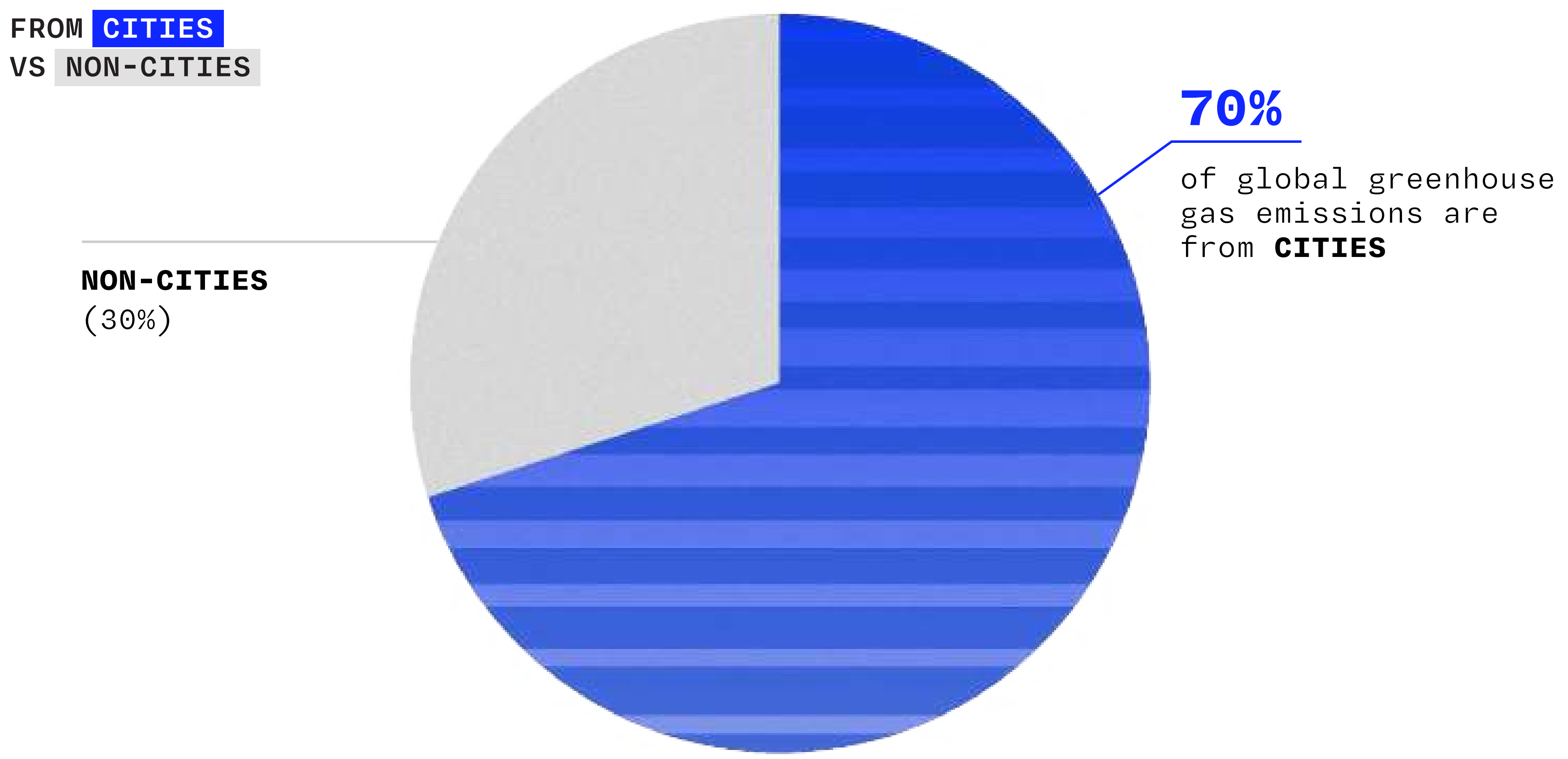


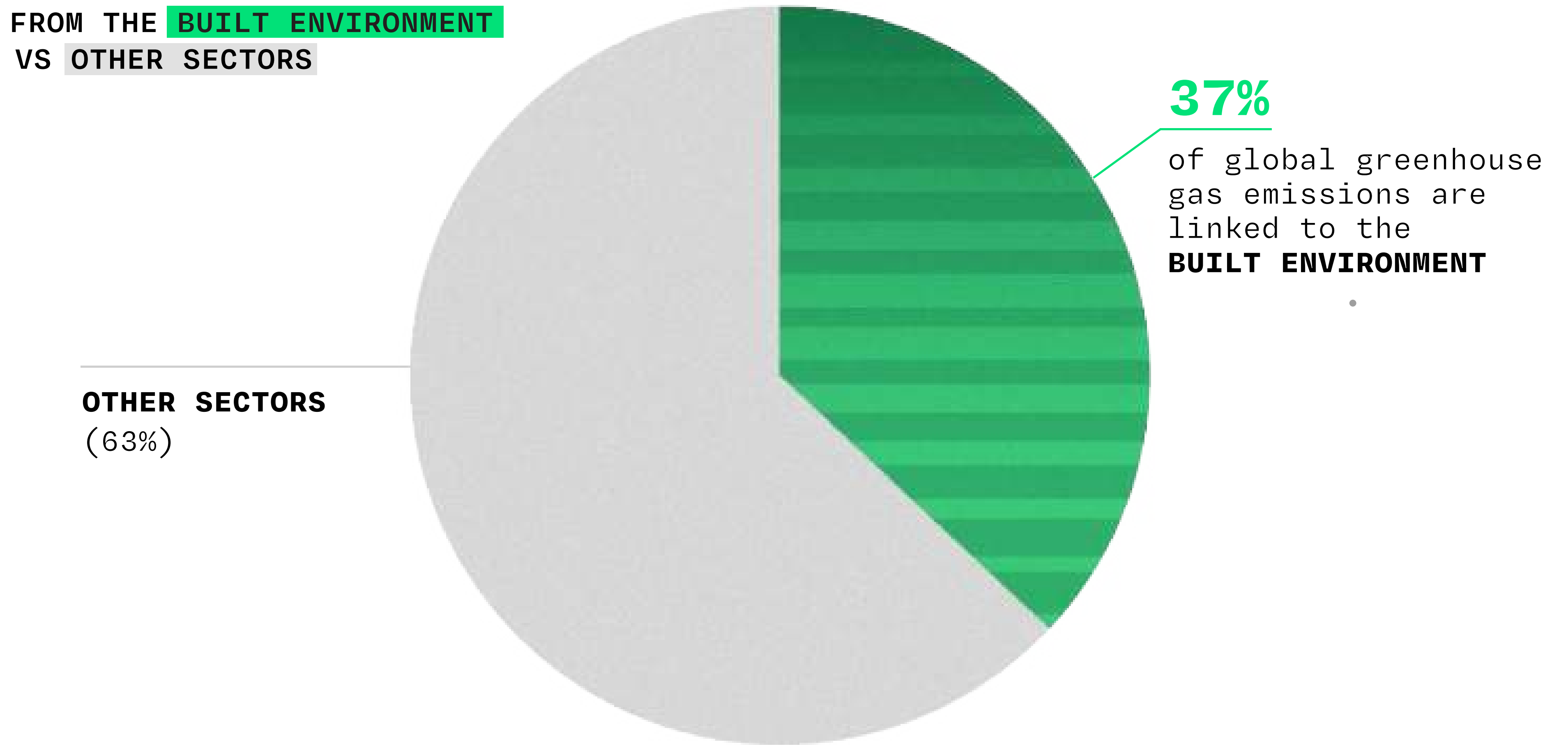
India is highly vulnerable to climate extremities, and it must elevate efforts to mitigate and build resilience against the effects of climate change.

The main driver of climate change is anthropogenic carbon emissions. Reducing CO2 emissions or decarbonisation within a certain time frame is an existentially important task, one that all nations must undertake together. As a ray of hope, the Paris Agreement offers a global framework of cooperation to systematically decarbonise and limit Earth's warming to less than 2 degrees Celsius by 2100.

Whether it is devastating floods or unbearable heat, cities face some of the worst impacts of changing climate. Building resilience against these impacts is the most urgent task. However, cities are also responsible for about 70 per cent of global GHG emissions and more than half of these emissions, i.e. about 37 per cent, are linked with the built environment. Without question, sustainability and decarbonisation of built environment is a top priority. The good news is that there is wide acknowledgement and understanding of the problem. However, there is big scope to ramp-up action, which is in line with the knowledge of decarbonisation and the solutions available.

ES1: Cities and especially the built environment are large contributors to global carbon emissions





[Source: C40 knowledge, International Energy Agency (2021)]

This report is an effort towards raising the collective consciousness of the building sector stakeholders and enhancing the adoption of low-carbon building solutions in their practices. Specifically, the report tries to respond to the question: **which solutions are technically feasible for adoption today that can create a significant impact at scale on carbon emissions from the built environment?** Through a data-driven approach, the report showcases solutions and exemplary case studies to illustrate that the work to bridge the gap between theory and action can start today. As the report reaches its intended audience, it will invigorate the conversation around decarbonising strategies and solutions, and inspire the stakeholders to act and implement.

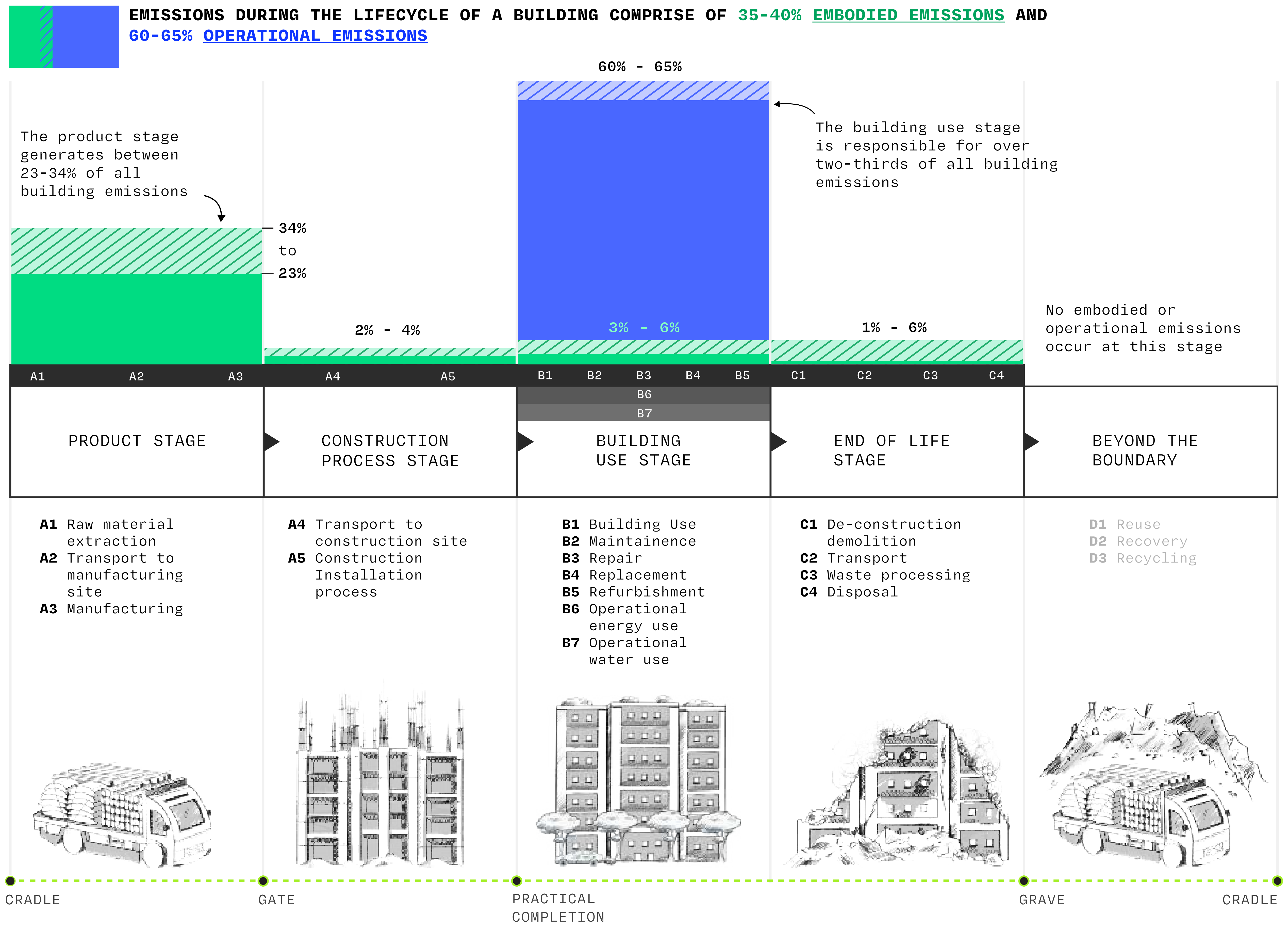
Understanding the carbon footprint of cities and approach to decarbonisation

An understanding of different kinds of carbon associated with the built environment is critical to comprehensively manage its carbon footprint. The lifecycle carbon footprint of a building has broadly two components: embodied carbon and operational carbon.

Embodied carbon (also known as hidden emissions) refers to the GHG emissions largely in the upstream activities of a building project including extraction, production, manufacturing, and transportation of materials. These materials are concrete, steel, aluminium, and other building materials such as plastics and glass. Embodied carbon represents about 11-13 per cent of total GHG emissions.

Operational carbon includes GHG emissions caused by energy use in buildings, primarily ascribed to cooling, heating, lighting equipment, lift etc. Globally, operational carbon represents about 25-27 per cent of total GHG emissions. Also, nearly 60 per cent of India's building sector emissions are due to operational carbon.

ES2: Building materials manufacturing and operational energy use are two big sources of carbon emissions in buildings



[Source: Adapted from Rocky Mountain Institute (RMI)[1] and Lawrence Berkeley National Laboratory (LBNL)[2] and IPCC report[3]]

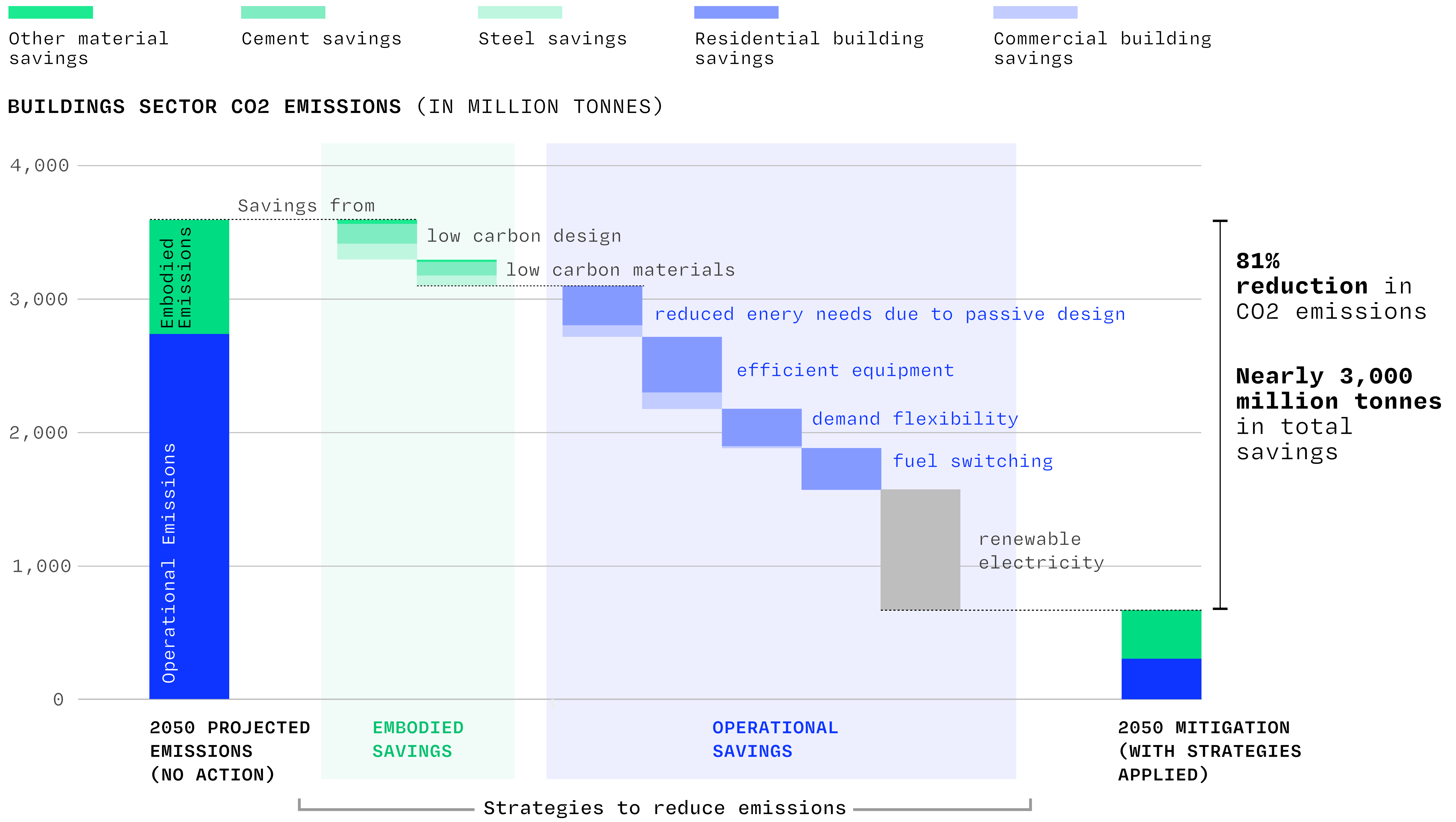
Climate-conscious urban forms

Urban form refers to the physical elements of a city such as block layout, distribution of green spaces, building types and land uses, but also includes intangibles like scale and density. Several approaches to the sustainable city paradigm exist as models of urban forms such as compact cities, eco-cities, green cities, new urbanism, and urban containment[4]. Cities must strive for sustainability through decarbonisation of buildings and other urban infrastructure with targeted technical solutions, while not losing sight of the importance of urban forms and city planning strategies. Solving for the problems at both levels – building and city – is important for long term sustainability of cities.

Towards decarbonising India's built environment

Reducing India's building sector's embodied and operational carbon requires a calibrated approach to decarbonisation instruments and solutions. These approaches must combine urban design interventions with decarbonisation technologies and strategies, be context-sensitive (catering to the vision of the city), balance cost with performance and offer possibilities for models of scalability.

ES3: The systematic deployment of available solutions and strategies is projected to put India's buildings sector on a net-zero pathway



[Source: Rocky Mountain Institute[5]]

ES4:

Four scales of decarbonisation solutions

Solutions for India's buildings sector decarbonisation are available. These solutions offer the potential to achieve net-zero buildings sector by 2050. These solutions can be categorised across four different scales of intervention.

CHAPTER 3

Urban Scale

Solutions that create impact when implemented across a given urban geography.

SOLUTIONS

1 **Innovative urban form and design**

2 **Green corridors**

3 **Cool rooftops**

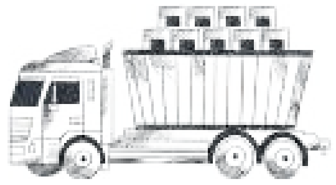
CHAPTER 4

Material & Design Scale

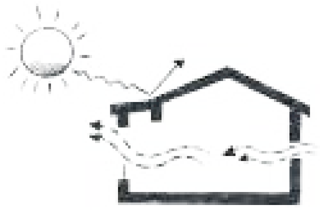
Reducing embodied and operational carbon by adopting low-carbon materials and lean and passive design practices

SOLUTIONS

1 **Low-carbon concrete and walling materials**



2 **Lean and passive design approaches**



CHAPTER 5

Building Scale

Cutting edge technology solutions replace or enhance existing building energy systems

SOLUTIONS

1 **Smart and renewable technologies**

2 **Radiant cooling with renewable integration**

3 **Retrofitting with high-efficiency systems**

4 **Retrofitting with energy management systems**

CHAPTER 6

Consumer Scale

Solutions that drive behavioural change in consumers by using nudges, awareness generation, and technology.

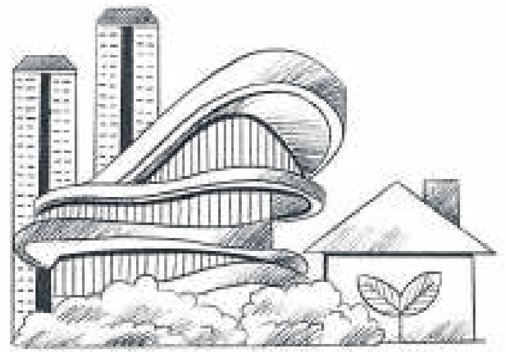
SOLUTIONS

1 **Renewable energy utilisation through prosumers**

2 **Leveraging mass media for consumer education on Net Zero Emissions houses**

Urban Scale

This is the scale at which solutions create impact when implemented across a given urban geography. The unit intervention may look small, but when scaled to the whole or part of the city, the aggregate impact is quite large.



Solution 1: Innovative urban form and design

It is not possible to prescribe one innovative approach but as an example, the Superblocks concept implemented in the city of Barcelona is truly inspiring. Superblock is a 400 m x 400 m mixed-use layout where the inner streets are closed off, while the traffic skirts around the buildings' outer perimeter. This design puts people in the centre shielded from the vehicles and vehicular noise and pollution, thus enhancing safety, air quality and noise quality experienced by people. If implemented as planned, the 503 superblocks will help reduce air pollution by 24 per cent[6], avoid 667 premature deaths annually[7], prevent 45 million euros in mental health costs annually[8], and increase the green cover by 5.67 per cent.[9]

Impact created

If implemented as planned, the 503 superblocks will help:

24%
reduction in air pollution

$45M
reduction in annual health costs

5.67%
increase in green cover

664
premature deaths avoided

Solution 2: Green Corridors

Medellin's Green Corridors have become a symbol of adopting nature-based solutions to solve for heat and air quality. Started with a plan to build 30 (12 waterways, 18 roads) interconnected Green Corridors, the $16.3 million 'Greener Medellin for you' programme has succeeded in planting more than 893000 trees and about 2.6 million other plants by 2021[10]. The species of trees and plants have been carefully chosen for their functional properties and potential to support urban biodiversity. Today the Green Corridors have given Medellin a reduction of 2 degree Celsius in average temperatures, an improvement in air quality through PM2.5 absorption, skills, and employment to more than 75 underprivileged people for gardening and maintenance services, and an estimated absorption of 160,787 Kg CO2 per year by the new vegetation growth in just one corridor[11]. The programme won the Ashden Prize in 2019 in the category of Cooling for People.

Impact created
By 2021, the plan had helped achieve:

893,000+
trees planted

75+
underprivileged people employed

~161,000 kg
CO2 / year absorbed

2°C
reduction in avg. temp

Solution 3: Cool Roofs

Cool roofs are a solution to decrease heat gain by the built environment. Conceptually, cool roofs are made of materials that are designed to reflect more sunlight than a conventional roof, thereby absorbing less solar energy. Telangana's Cool Roof Programme aims to cover 300 square kms of area over the next 5 years. The policy mandates cool roofs for all the government, non-residential, and commercial buildings. Residential buildings with a plot area of 600 sq. yds. or more are also required to have cool roofs, while smaller residential buildings have the option to voluntarily build them. The policy aims to achieve projected savings of 600 million Units (GWh) of electricity annually after five years.

Impact created
Targets for the next 5 years:

300 sq. kms
of cool roofs

~600M
Units (GWh) of electricity saved

Material and Design Scale

This is the scale at which one encounters a large decarbonisation opportunity as a lot of embodied and operational carbon can be reduced by adopting low-carbon materials and lean and passive design practices. Combining low-carbon materials with optimised design offers compounding benefits.

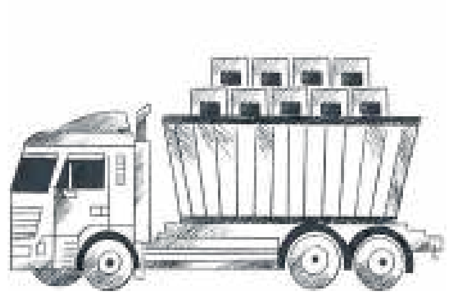
Solution 1: Lean and passive design approaches

Smart Ghar, Rajkot, is a project known for providing thermal comfort to occupants in the building using affordable construction materials, and modulation in the building design. Passive design strategies in this building include optimised opaque building envelope, use of sustainable materials and natural ventilation. By adopting these passive design measures, it is estimated to reduce peak summer room temperature by >5°C, as well as increase the number of comfortable hours (those below 30°C) from ~2600 hours to ~6300 hours across the year. A post occupancy survey at this development showed that 40 per cent respondents reported indoor temperature and air movement to be satisfactory during the summer and monsoon months, while 60 per cent of the respondents reported the relative humidity to be neutral or on the satisfactory spectrum (20 per cent) in the summer and monsoon seasons.

Impact created

5°C ▼ **reduction in peak summer room temperature**

2.7x **increase in comfortable hours (under 30°C) annually**



Solution 2: Low-carbon concrete and walling materials

LC3 or Limestone Calcined Clay Cement is a promising and cost-effective technical solution to deal with this problem. A 50 kg bag of LC3 is a pre-mix of 50 per cent OPC cement blended with 50 per cent of substitute materials, namely, 15 kg of calcined clay, 7.5 kg of uncalcined limestone and 2.5 kg of gypsum[12]. LC3 has lower emissions because clay calcination occurs at lower temperature (800°C) and there is no decomposition of limestone as the limestone in LC3 is mixed without burning. LC3 therefore can reduce about 40 per cent of emissions associated with cement production.

There are several examples of building materials that perform well on parameters like embodied energy, thermal transmittance, and bulk density. Two such masonry walling materials - hollow clay blocks and auto-claved aerated concrete (AAC) blocks, are compared with the conventional solid fired clay bricks.

Impact created

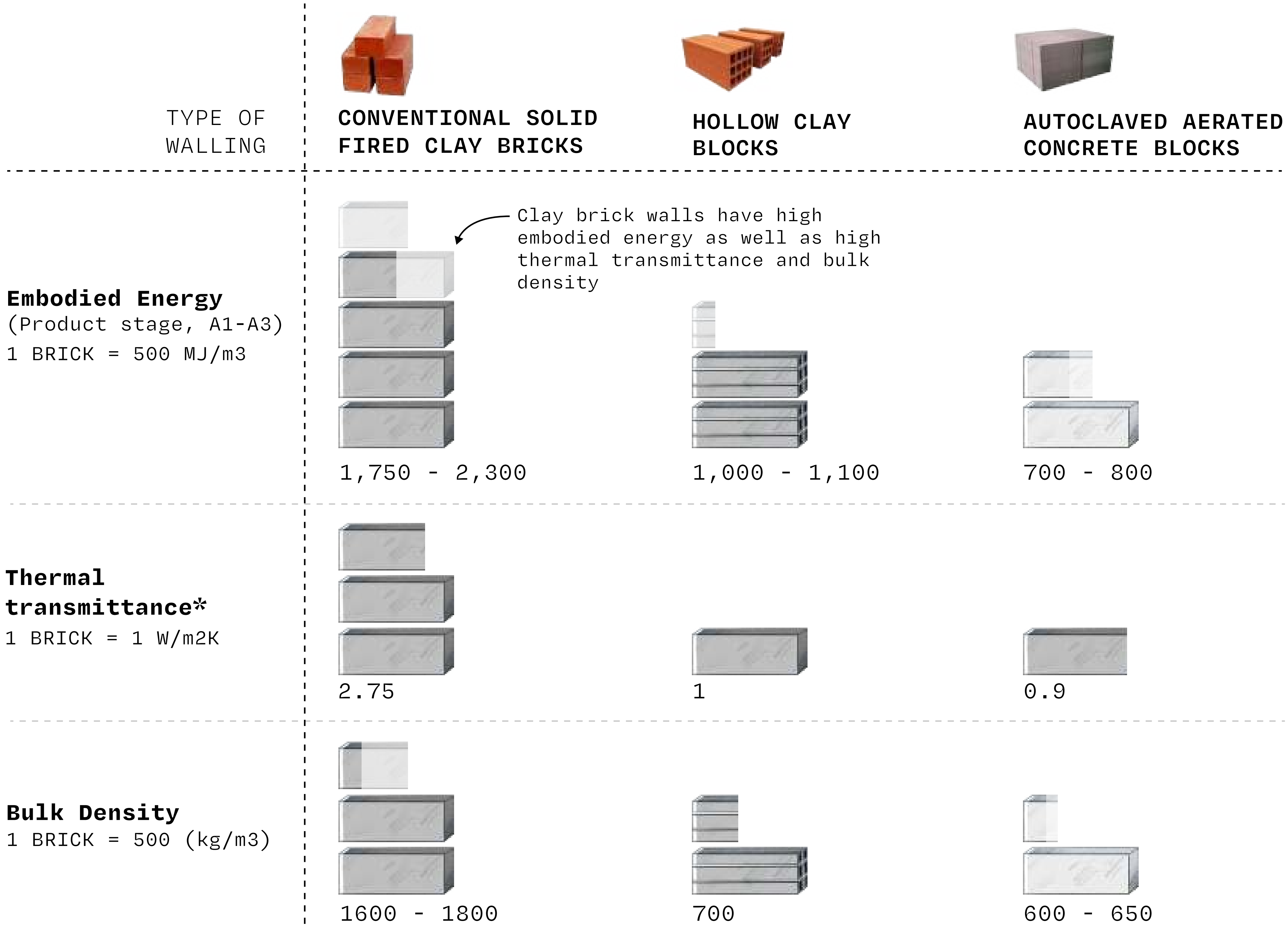
40%

of emissions associated with cement production can be reduced with LC3

60-70%

lower thermal transmittance and embodied energy

ES 5: The alternatives to bricks should be compared across several parameters to achieve the most applicable solution



[Source: Authors' analysis and illustration]

Note: Thermal transmittance is a function of thermal conductivity and thickness of the material. These bricks and blocks are available in the market with varying thickness values. For comparison purposes, 200 mm thickness is considered for all the materials.

Building Scale

This is the scale at which cutting edge technology solutions replace the existing building energy systems or integrate with them. Interventions at this scale offer a massive opportunity to tackle operational energy use in buildings.

Solution 1: Smart and renewable technologies

The Coral Headquarters in Bangkok has achieved an impressive 70 per cent reduction in energy demand as compared to conventional buildings in the warm and humid climate of Bangkok. This energy-efficient building incorporates a range of advanced technologies, and active systems to minimise its environmental footprint while maintaining superior indoor comfort. The building integrates smart IoT technology to monitor indoor air quality and temperature in real time. When outdoor temperatures drop below a certain threshold, the system automatically switches to use the free cooling effect from outside air, reducing the need for mechanical cooling. It also incorporates solar PV systems to generate 30 per cent of its energy needs on-site, making Coral HQ 39 a net-zero energy building. Maintaining indoor environment quality across the year in the urban areas is a challenge. The project has set a precedent for better quality of life for its users using an effective thermal comfort system and IOT technologies.

Impact created

70% reduction in energy demand

30% of energy needs generated on-site using solar PV systems

Net-zero status achieved

Solution 2: Radiant cooling with renewable integration

Gainwell CAT office building, located in Greater Noida (composite climate), is a 3-storey building with an area of 4,945 m², and part of the 5-acre Industrial campus, completed in 2018. The building incorporates integrated design approach, climate responsive high-performance building design, low energy cooling system and integrated renewable energy system. The technologies integrated in the building include Low Energy Radiant Cooling System, combined with Interconnection of Passive and Active Free Cooling Systems using IOT technologies, and a 100-kw Solar Photovoltaic system, which caters to 40 per cent of the energy needs in the building.

Impact created

100kW Solar PV System

40% of energy needs generated on site

❄ Low Energy Radiant Cooling System

Solution 3: Retrofitting with high-efficiency systems

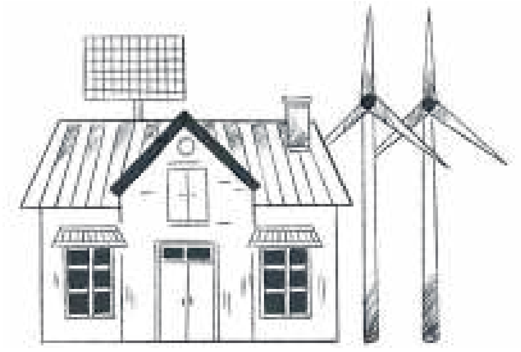
The UN House building located in Lodhi Estate, Delhi, has undergone a major energy-efficiency retrofit and renewable energy integration through which the energy performance and the greenhouse gas emissions associated with energy use have been reduced by up to 48 per cent. The building received the LEED green building certification for facility operations and management under O+M: Interiors category with Platinum level (Sustainability Score of 87/100). The building has received the National Energy Conservation Award India – 2020 under the Office Buildings Category and GRIHA 4-Star Rating.

Impact created

48% reduction in energy-related emissions

87/100 Sustainability score in LEED Platinum certification

★ Recognised with the National Energy Conservation Award in 2020



Solution 4: Retrofitting with energy management systems

Apollo Hospitals and Smart Joules launched Project Virya in 2021 which aims to save 235 million kWh of energy and reduce 290,000 tonnes of CO_2 emissions in a 10-year time frame. The ambitious goal is being achieved through system design enhancements, digitization of energy and related equipment and systems, intelligent data-driven automation of operations, training of key personnel, and careful ongoing operations and maintenance management. The energy efficiency retrofits in Apollo hospitals included new ultra efficient energy efficient chillers, variable speed pumping systems, automated condenser tube cleaning systems, low approach cooling towers, LED Lights, BLDC Fans, modulating valves & VFDs for AHUs, deep instrumentation with intelligent energy monitoring, analysis, and intelligent control technology. The other interventions deployed in the hospitals under this project included heat pumps for hot water generation to transition from diesel and gas-based heating to electric heating, revamped laundry systems with new efficient electrical heating systems.

Impact created

Goals to achieve in 10 years:

235 million
kWh energy saved

290,000
tonnes of CO_2 emissions reduced

Consumer Scale

Behavioural change is an essential aspect of decarbonisation impacting the operational carbon emissions. This scale is important to introduce behavioural nudges, awareness generation in the end consumer, but also built technology platforms that can leverage the degrees of control available to consumers and contribute to decarbonisation.

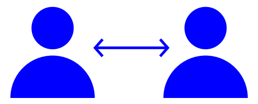
Solution 1: Renewable energy utilisation through prosumers

Power Ledger has enabled peer-to-peer (P2P) trading in the T77 precinct of Bangkok, Thailand by educating the consumers on the benefits of using clean energy and maximising energy efficiency in their households. As a result of the platform, the total solar generation capacity of the T77 project has increased from 2.8MWh daily solar generation across 4 buildings to 4.2MWh across 7 buildings. In India, a pilot project with the Government of Uttar Pradesh has demonstrated the feasibility of PowerLedger's platform to trade energy from rooftops with solar power to neighbouring households and buildings. This has enabled the definition of the network tariff that will support the wider rollout of P2P electricity trading across the state.

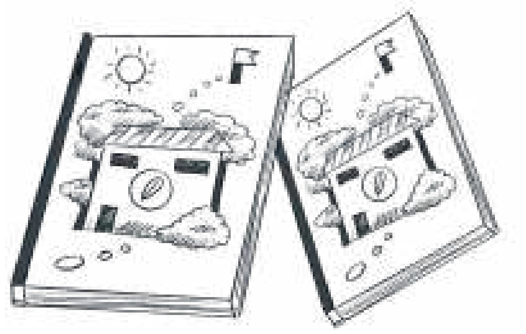
Impact created

1.5x

increase in daily solar generation across Bangkok's T77 precinct, going from 4 building partners to 7



Pilot project in Uttar Pradesh supporting P2P energy trading rollout



Solution 2: Leveraging mass media for consumer education on Net Zero Emissions houses

A successful story on education and awareness emerged from Japan, where the Ministry of Environment; Ministry of Land, Infrastructure, Transport and Tourism, and Ministry of Economy, Trade, and Industry (Agency for Natural Resource and Energy) promote a climate-friendly building policy. The programme helped the citizens to understand clearly the concepts of NZEB, Passive Cooling, Nature-based solutions, etc. The outreach materials used by the ministries emphasise on showcasing the know-how on measures to reduce energy bills and make a net zero home in the country. The programme was noted for its use of popular medium like Manga and stand-up comedians for knowledge and awareness generation.

Impact created

Engages citizens through mass media formats such as Manga and stand-up comedians

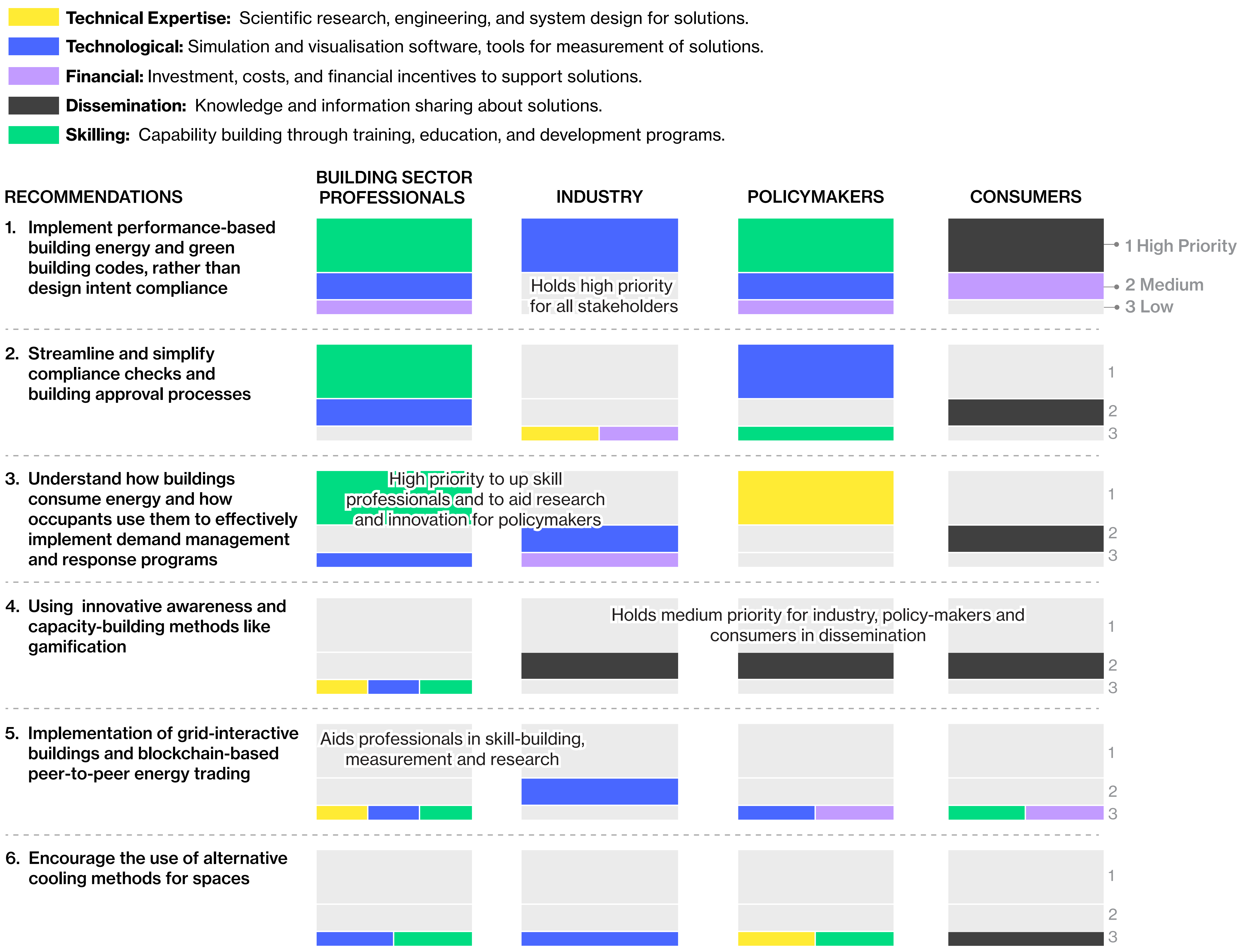
Promotes climate-friendly building policies nationwide

Focuses on reducing energy bills and achieving net zero energy homes

Stakeholder convergence for action and impact

The engagement within the stakeholder ecosystem can provide the crucial impetus for making large scale adoption a reality. The urban scale solutions provide a useful backdrop to policymakers and urban planners in thinking about radical and pragmatic urban forms and designs, especially with an eye to solve for low-income settlements through affordable interventions. The design and material scale offers crucial lessons for synergy between several stakeholders such as cement producers, material innovation companies as vendors, architects, construction companies and builders themselves. Likewise, the building scale offers direction to builders and construction players in how to plan and integrate design and technology driven solutions at different stages of a building life cycle. Consumer scale interventions in the form of behavioral nudges and awareness building exert a huge impact on energy consumption during the building use cycle. Through analysis of different challenges and contexts, several recommendations emerge for a varied stakeholder base for greater adoption of the proposed solutions and implementation strategies. These recommendations can be suitably prioritised (ES6) by specific stakeholders as per the impact and degrees of control they exert over specific areas.

ES6: Prioritization of actionable recommendations by different stakeholders can lead to building ecosystem convergence



[Source: Authors' analysis and illustration]

CHAPTER 1

Climate Challenge and Conscious Collective

ES
1
2
3
4
5
6
7
8

India is poised to become the world's third largest economy with projected gross domestic product (GDP) upwards of $5 trillion by 2026.[13] As agriculture's contribution to GDP declines, urban areas become crucial for economic productivity and job creation.

Propelled by rapid urbanisation, India's building stock is undergoing significant transformation.

Commercial floor space constructed every day in India	300,000 sq. ft.
Next 20 years of India's building stock which is yet to be built	40%

On the flip side, climate change will pose a substantial challenge to India's growth ambitions. For instance, 4.5 per cent of India's GDP is potentially at risk due to labour productivity loss from rising extreme heat by 2030.[14] Such climate risks pervade through most other sectors as well. India can altogether lose up to 10 per cent of its GDP annually by 2100 due to climate change.[15,16]

The 2015 Paris Agreement set ambitious targets to limit global warming to well below 2°C with efforts to restrict it to 1.5°C. Several countries, including India, have declared their plans to become net-zero in pursuit of limiting global warming. These national plans feature decarbonisation as a critical strategy to deal with climate change by reducing the carbon dioxide (CO2) emissions resulting from human activities.

The buildings sector globally offers a huge opportunity for reducing CO2 emissions. Buildings and construction sector account for nearly 37 per cent of global CO2 emissions.[17]

India's urban population is expected to rise from 377 million in 2011 to 590 million in 2030.[18] Propelled by rapid urbanisation, India's building stock is undergoing significant transformation. The construction sector is projected to witness substantial expansion over the coming decades, driven by increasing demand for both residential and commercial spaces. At present, India is constructing approximately 300,000 square feet of commercial floor space every day.[19] Moreover, 40 per cent of India's building stock which will exist in the next 20 years is yet to be built.[20]

Decarbonisation of the built environment in India has also been challenging over the years, owing to a) limited adoption of and compliance with energy conservation building codes (ECBC) at local level, b) lack of consideration to tackle embodied carbon in buildings, c) consumer behaviour around comfort and energy use, and d) lack of investment in low-carbon materials and sustainable building practices keeping scale elusive and costs high for consumers.[21]

1.1 Significance of Conscious Collective

Several bottlenecks inhibit the low-carbon transition pathway in the buildings sector. One of those bottlenecks is the lack of adoption of low-energy, low-carbon solutions by the builder's community and end-consumers. It can be driven through policy incentives and regulations, but also through market innovation which can create affordable and accessible options. Critically, shaping a conscious consumer will have to be placed at the core of both these approaches.

What defines a conscious consumer? Conscious consumerism involves making intentional purchasing decisions that reflect one's values, particularly concerning social, environmental, and ethical considerations. It encourages consumers to think critically about the products they buy, the companies they support, and the broader impact of their consumption habits on society and the environment. A conscious consumer can help catalyse a virtuous production-consumption cycle by supporting sustainable offerings by businesses and adopting mindful utilisation of resources.[22]

Some of India's flagship initiatives have also placed conscious consumers at the front and centre of sustainability discourse. For example, Mission LiFE (Lifestyle for Environment), an India-led global mass movement launched by Prime Minister Narendra Modi at COP26 in Glasgow in November 2021, aims to promote sustainable lifestyles and nudge individual and community action to protect and preserve the environment.[23, 24]

The fascinating idea of a *conscious collective* – that of experts and practitioners in dialogue to mobilise and influence a conscious consumer – is very much anchored within the policy frameworks like Mission LiFE, Star Labelling Scheme and Right to Repair. *The Conscious Collective* seeks to deliberate on the sustainable options available to consumers, highlight their benefits and offer pathways to scale these solutions. The report is an attempt to provide a springboard for the *conscious collective* by prescribing easy-to-adopt solutions for consumers and building sector stakeholders to address CO2 emissions at different stages of a building lifecycle.

1.2 Objectives and approach of the report

In the last few years, sustainability conversations have really entered the mainstream. The recognition is growing that people and systems must be conscious of and deliberate about their impact on the planet. With this background, the report tries to respond to the question: which solutions are technically feasible for adoption today that can create a significant impact at scale on carbon emissions from the built environment?

Methodology: The report curates representative case studies that have adopted low-carbon solutions to achieve resilience and decarbonisation. The major emphasis while making the selection of low-carbon solutions is on ease of adoption for the target audience (builder, designer, planner, or homeowners). Further, the methodological approach is informed by the following:

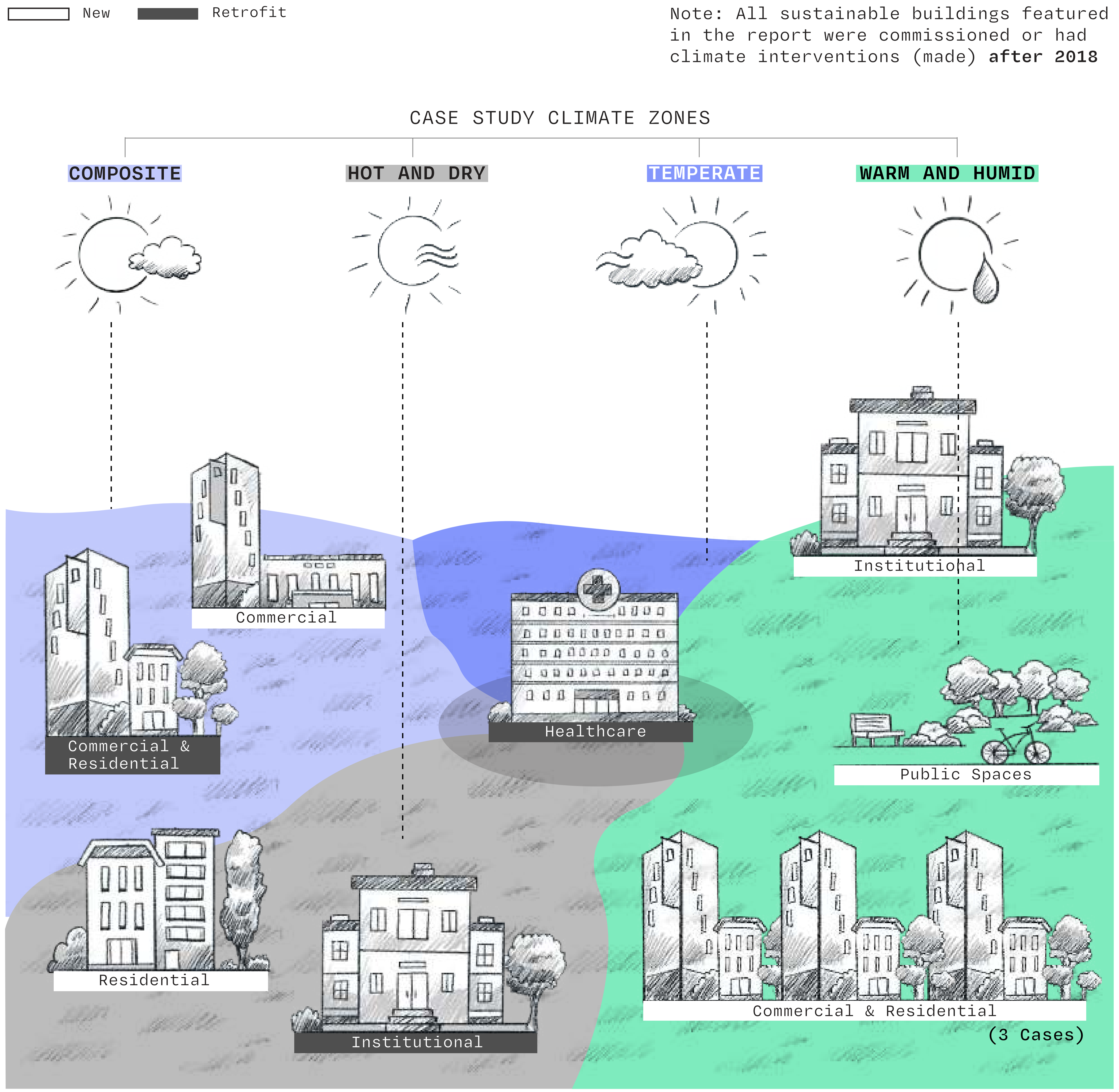
1. The report emphasises on showcasing the approaches for decarbonisation of built environment based on lean design and passive design principles, which focus on resource efficiency during construction and reducing operational needs for energy.
2. In addition to highlighting the successful integration of sustainable solutions in building projects, the report also adds a layer of performance data and implementation analysis to deconstruct why the project in question became a success.
3. The report is very much embedded in the thinking of adoption-at-scale. The scale lens is therefore very important to the discussion of solutions. The case description and analysis will cover the costing and feasibility aspects of the solutions, which are essential to achieving scale.

Criteria for selection: The case studies have been selected from different contexts for their innovation and impact. These examples cover the four solution cohorts that can help reduce the carbon footprint of the built environment in cities, namely, Urban interventions, Design and materials, Technologies for clean and efficient energy, and Behavioural interventions. Moreover, the report brings forth a diversity of cases from different climate zones, building types and policy/institutional contexts (Exhibit 1). About 10 such projects have been covered in detail in the report.

Validation from experts and project designers: The performance data and other operational details about the cases have been validated through experts and project designers. In addition, the report will feature a few quick perspectives from the community of designers and project implementers to endorse support for the solutions.

This report looks at case studies from 4 countries, including India

EXHIBIT 1: The cases showcased in the report cover a variety of climate and use contexts



[Source: Author's analysis]

1.3 Expectations from the report

There are several use-cases for the report. It aspires to become a reference for building ecosystem players, particularly the architects, designers, real estate developers and policy professionals, to discuss the relevance and prioritisation of proposed solutions for India.

Consequently, the report would want to catalyse action by drawing attention to the costs, performance, and policy levers available to drive offtake of proposed solutions. Lastly, the book is also an attempt to showcase world class solutions and initiatives being implemented in India, and derive the key learnings of how the ecosystem of stakeholders needs to move forward.

CHAPTER 2

Cities at Crossroads of Climate Change

In 2024, India experienced one of its most severe heat waves since 1951, with more than 37 cities recording temperatures exceeding 45 degrees Celsius.[25] The national capital, New Delhi, faced a heat crisis and a water-logging crisis caused by unprecedented rains, just days apart from each other.

More than 75 per cent of Indian districts are hotspots for extreme weather events.

37 cities in India recorded temperatures exceeding	45°C
High density areas like Dharavi in Mumbai are hotter by	6°C

This is the new normal for many cities around the world: having to deal with unpredictable and extreme weather events (EWE) linked to climate change throughout the year. More than 75 per cent of Indian districts are hotspots for extreme weather events.[26] Altogether, India features high on climate vulnerability and is severely impacted by weather-related loss events.[27] The unplanned nature of India's megacities coupled with high densities and slums have resulted in significant variations in microclimates as well. Dharavi in Mumbai for instance can be about 6 degrees Celsius hotter than its adjoining, more affluent neighbourhoods.[28]

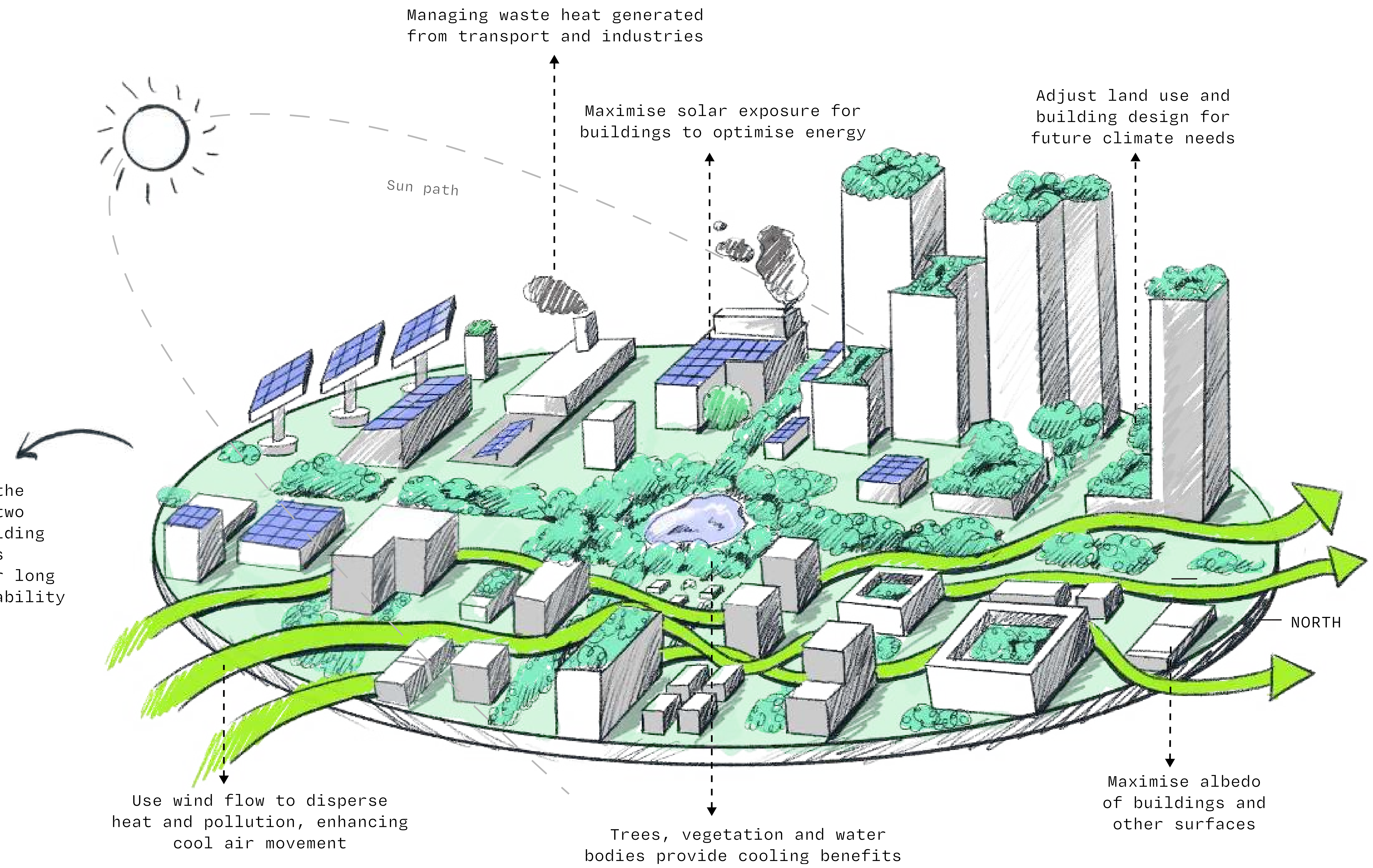
The anxiety about extreme weather (heat, rain, cyclones) is worsened by the rising consumption levels of cities, especially in emerging countries such as India. It creates the vicious loop of increasing GHG emissions and further compounding of the climate crisis. The response to these challenges must come in several ways. In addition to decarbonisation of its buildings, transportation, and industrial sectors, we need to work on the design elements of our cities, and deploy urban strategies that are conscious and responsive to changing climate.

2.1 Climate-conscious urban forms

Urban form refers to the physical elements of a city such as block layout, distribution of green spaces, building types and land uses, but also includes intangibles like scale and density.

Several approaches to the sustainable city paradigm exist as models of urban forms such as compact cities, eco-cities, green cities, new urbanism, and urban containment.[29] Cities must strive for sustainability through decarbonisation of buildings and other urban infrastructure with targeted technical solutions, while not losing sight of the importance of urban forms and city planning strategies. Solving for the problems at two scales – building and city – is important for long term sustainability of cities.

EXHIBIT 2: Urban forms not only impact key aspects of human life, including mobility, health, and physical activity, but also correlates with response to climate change, especially heat resilience



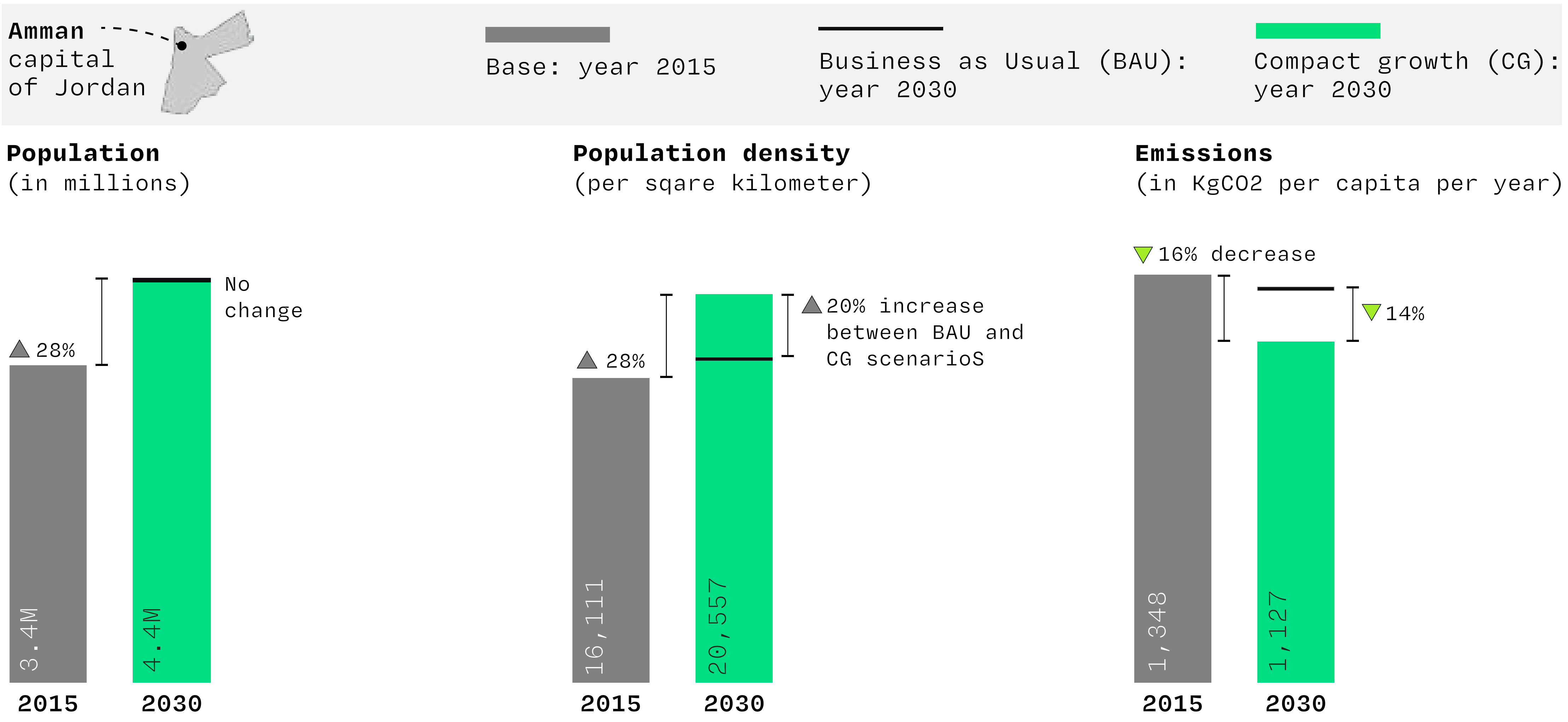
[Source: Urban Climate Lab[30]]

Importance of urban design

A growing body of evidence from diverse contexts points to the impact urban forms can have on the Urban Heat Island (UHI) phenomenon, vulnerability to floods and GHG emissions.[31, 32, 33] Quantifying the impact of urban form and design on a city's emissions or heat can be done through urban modelling. However, the relative impact of urban form interventions can be very different from one place to another. These impacts depend on a city's current density and land use mix, transportation mode share, building stock, rate of population growth, and other factors.[34] It is therefore more meaningful to examine the impact only at the city level, and not across cities.

One can note the impact of urban design in Amman (Jordan) from the modelling results of a World Bank study.[35] In the complex growth scenario by 2030, new growth is close to jobs and public transportation allowing for housing densities to reach the maximum limit. Moreover, no new spatial growth takes place with the increase in urban population. About 14-16 per cent emission reduction was projected through alternative urban designs and interventions. The GHG emissions in the model were from energy consumed for public lighting, municipal water supply, solid waste management, electricity use, public transportation, and private vehicles.

EXHIBIT 3: The city of Amman decreased its projected emissions through urban design and planning



[Source: World Bank]

The juxtaposition of design and form of two leading cities reveals a simple but important point. The strategies applied in Copenhagen would not have worked in Japan as scale and density of the two places do not match.

Understanding context is important for urban scale interventions!

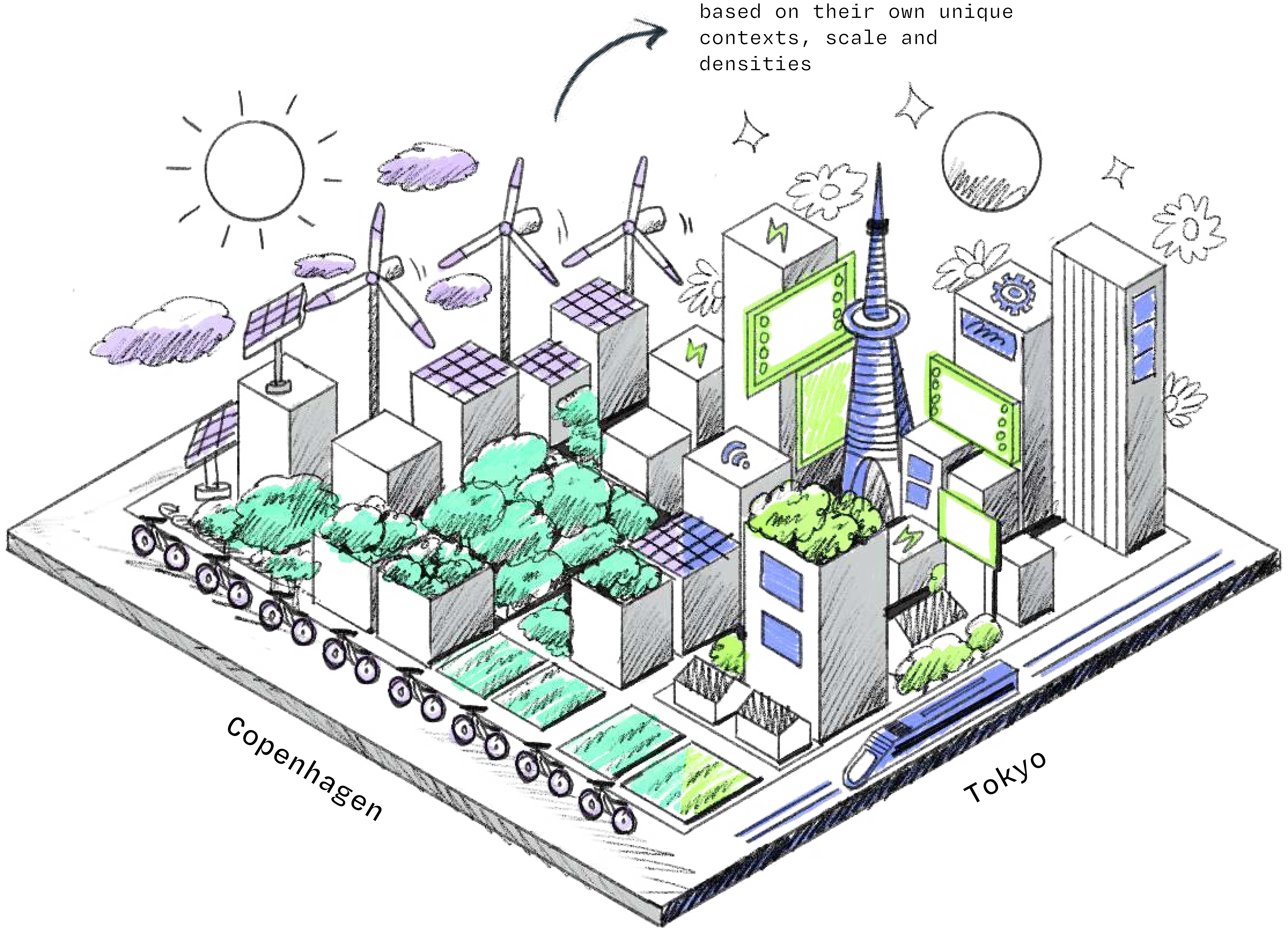
Context is very important for urban forms, or to deploy other urban strategies. Take the case of two leading cities – Tokyo and Copenhagen. In 2022, the two cities were ranked 3 and 4 respectively in the Sustainable Cities Index.[36] However, the urban design and form of the two cities are markedly different.

Copenhagen is known for its human-scale architecture, extensive bicycle routes and interconnected green spaces. The core of the city's identity is sustainability and liveability, also captured in its commitment to become carbon neutral by 2025.[37] The city's per capita carbon emissions are estimated to be lower than the national average. Tokyo, on the other hand, stands for technological innovation and tradition: its built environment is a mix of ultra-modern skyscrapers, serene temples, gardens, and wooden houses. Evidently, the urban forms reflect the tension between the need to accommodate one of the largest metropolitan populations and preserve its cultural and historical identity.

The juxtaposition of design and form of two leading cities reveals a simple but important point. The strategies applied in Copenhagen would not have worked in Japan as scale and density of the two places do not match. It shows that sustainability pathways adopted by cities are significantly determined by *a priori* contexts, leading to highly tailored urban design solutions and tangible choices made for buildings, mobility, and other urban infrastructure.

In India, several city level initiatives are underway to reduce hazard risk and improve quality of life and public spaces. Under city investments to innovate, integrate and sustain (CITIIS), 12 cities have been undertaking efforts to improve green-blue infrastructure, ease of mobility, biodiversity, heritage conservation etc.[38] Mumbai has launched its first ever climate budget for 2024-25, the 4th municipal corporation in the world to do so.[39]

Some of these urban/city scale strategies and case studies to build resilience towards rising urban heat, as well as complement building decarbonisation solutions are discussed in chapter 3.



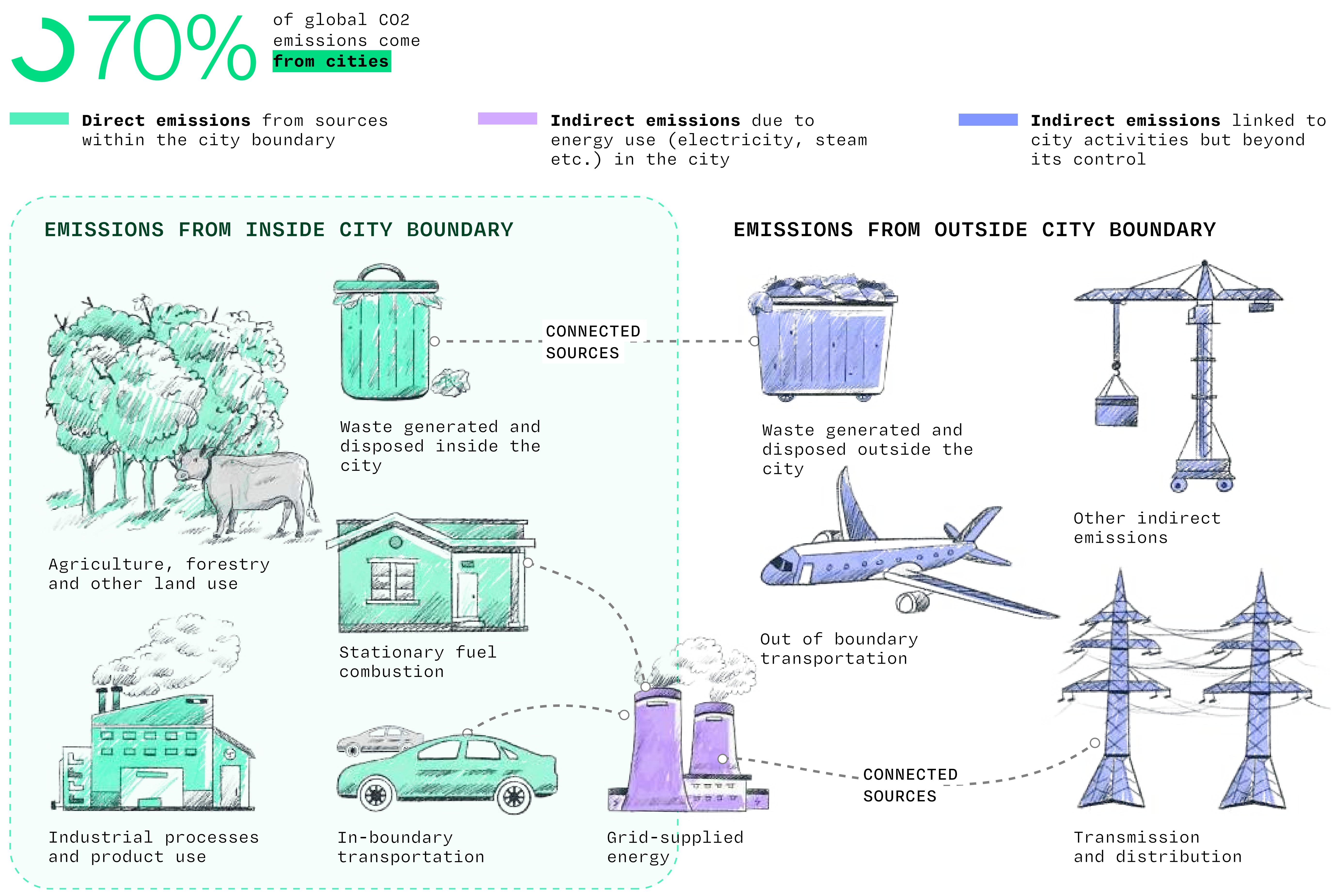
2.2 The carbon in our cities

Beyond the urban forms shaping sustainable cities, decarbonisation of cities must be the most important endeavour in the response to climate change. Several estimations suggest that urban areas are responsible for about 70 per cent of global CO2 emissions, with transport and buildings contributing the highest share.[40] Consumption and sectoral emissions of a city together form the total city level emissions. Exhibit 4 shows the sectoral activities responsible for a city's emissions that are within and outside city boundaries. The discussion in this section is limited to the buildings sector as it is a large contributor as well as a complex ecosystem.

An understanding of different kinds of carbon associated with the built environment is critical to comprehensively manage its carbon footprint. A whole-systems approach to decarbonisation dealing with all forms of carbon emissions across a building lifecycle will be needed for a net-zero buildings sector. Depending on the stage of the building lifecycle, the CO2 is categorised in two ways: embodied carbon and operational carbon.

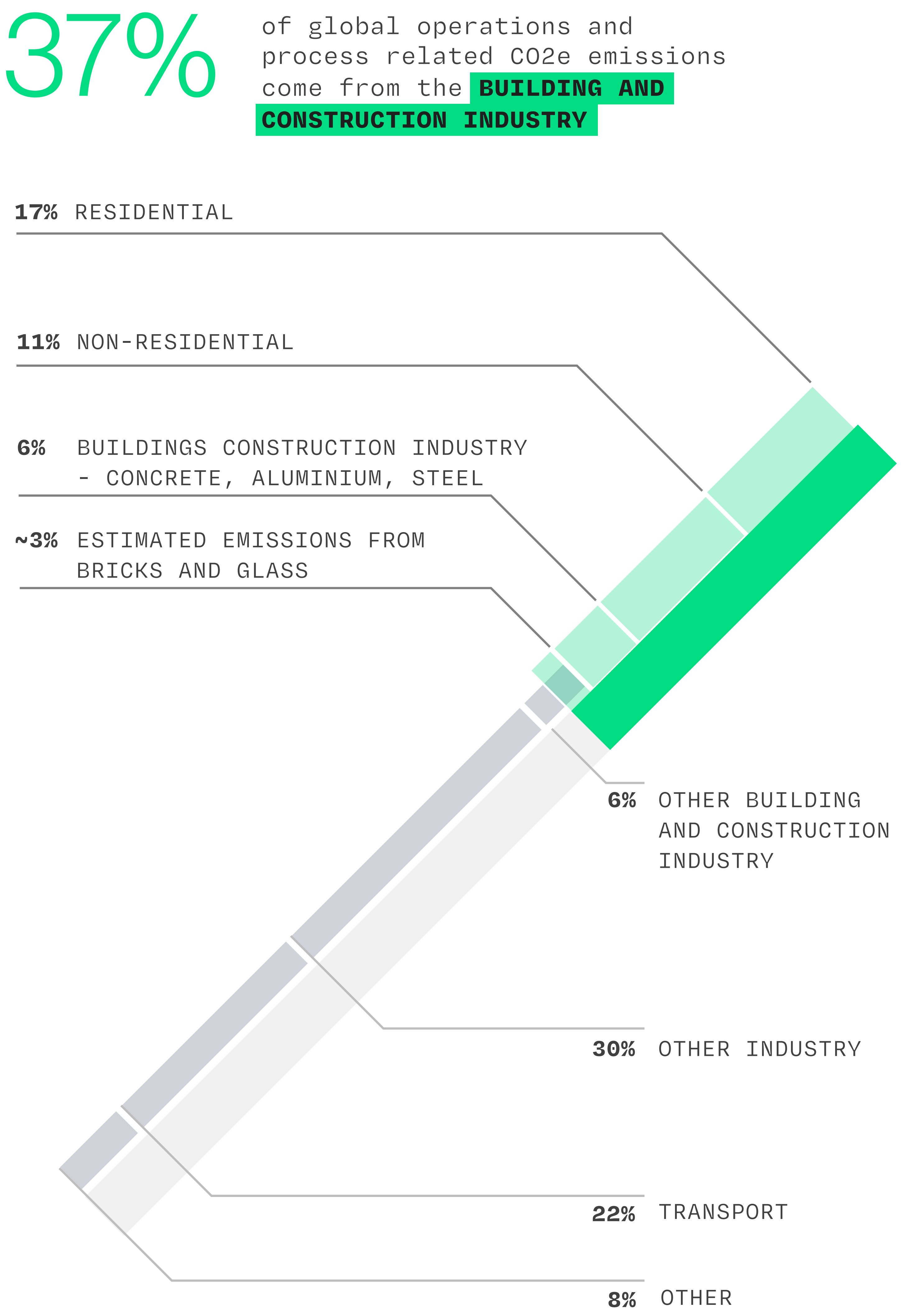
A complex ecosystem of contributors to urban emissions

EXHIBIT 4: Total GHG emissions of a city are a combination of consumption-based and sectoral emissions.



[Adapted from source: C40 Knowledge Hub[41]]

EXHIBIT 5: Share of buildings operations and process related CO2e emissions in 2021



[Adapted from source: International Energy Agency[42]]

Note: Buildings construction industry and other construction industry refers to concrete, steel and aluminium for buildings and infrastructure construction respectively. The boundaries of the emissions (energy and process) account for construction materials included from raw materials preparation and processing and the different steps to produce the materials. For example, for cement this includes the entire manufacturing processes, from obtaining raw materials and preparing the fuel through to grinding and milling. The numbers in the chart are rounded values and therefore do not necessarily sum to the total value for a given sector.

Embodied carbon (also known as hidden emissions) refers to the GHG emissions largely in the upstream activities of a building project including extraction, production, manufacturing, and transportation of materials. These materials are concrete, steel, aluminium, and other building materials such as plastics and glass. As defined by the European Standard EN 15978, the embodied carbon of buildings is accumulated across the building lifecycle starting from material production until the demolition and disposal of the buildings.

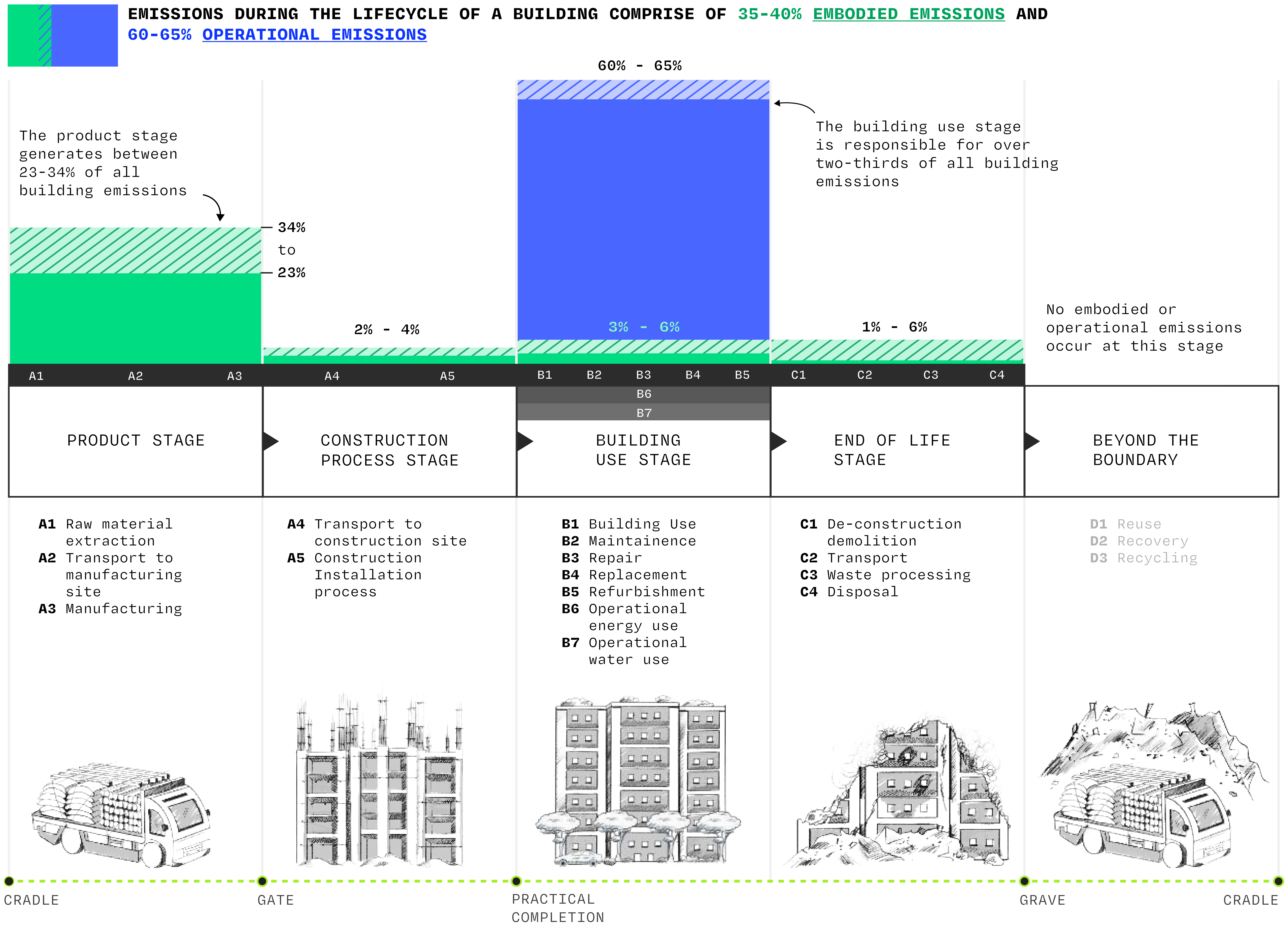
The upfront embodied carbon or the embodied carbon to the practical completion of the building comprises stages A1 to A5 (Raw material supply to construction). The whole life embodied carbon comprises the stages A1-A5, B1-B5 (Operational use, maintenance, and replacements), and C1-C4 (Demolition to disposal). The B6 represents the operational carbon of the buildings.

As for the share of embodied carbon from the building and construction sector, globally it is estimated to be around 11-13 per cent of the total GHG emissions.[43, 44] In India, the share of embodied carbon in total building emissions is close to about 40 per cent[45, 46], implying the significance of embodied carbon reduction solutions for decarbonisation of the sector.

A break-up of the share of embodied carbon also structures the challenges and opportunities associated with decarbonising different stages. For instance, substituting carbon intensive building materials with better alternatives must drive the strategy to reduce embodied carbon. Other levers of transformation can be recovery and reuse of building materials, alternative uses of construction debris at the end of life and efficient construction technologies.

Operational carbon includes GHG emissions caused by energy use in buildings, primarily ascribed to cooling, heating, lighting equipment, lift etc. In 2022, globally building operations accounted for 30 per cent of energy use and 26-27 per cent of energy-sector related emissions.[47] Nearly 60 per cent of India's building sector emissions are due to operational carbon. Operational carbon can be further segregated into direct and indirect emissions, depending on whether emissions are located on-site or off-site. Moreover, India Cooling Action Plan estimates refrigerant-based cooling potentially contributing 70 per cent of building operational emissions in unmitigated scenarios.[48]

EXHIBIT 6: Detailed labelling of different kinds of carbon associated during the lifecycle of a building



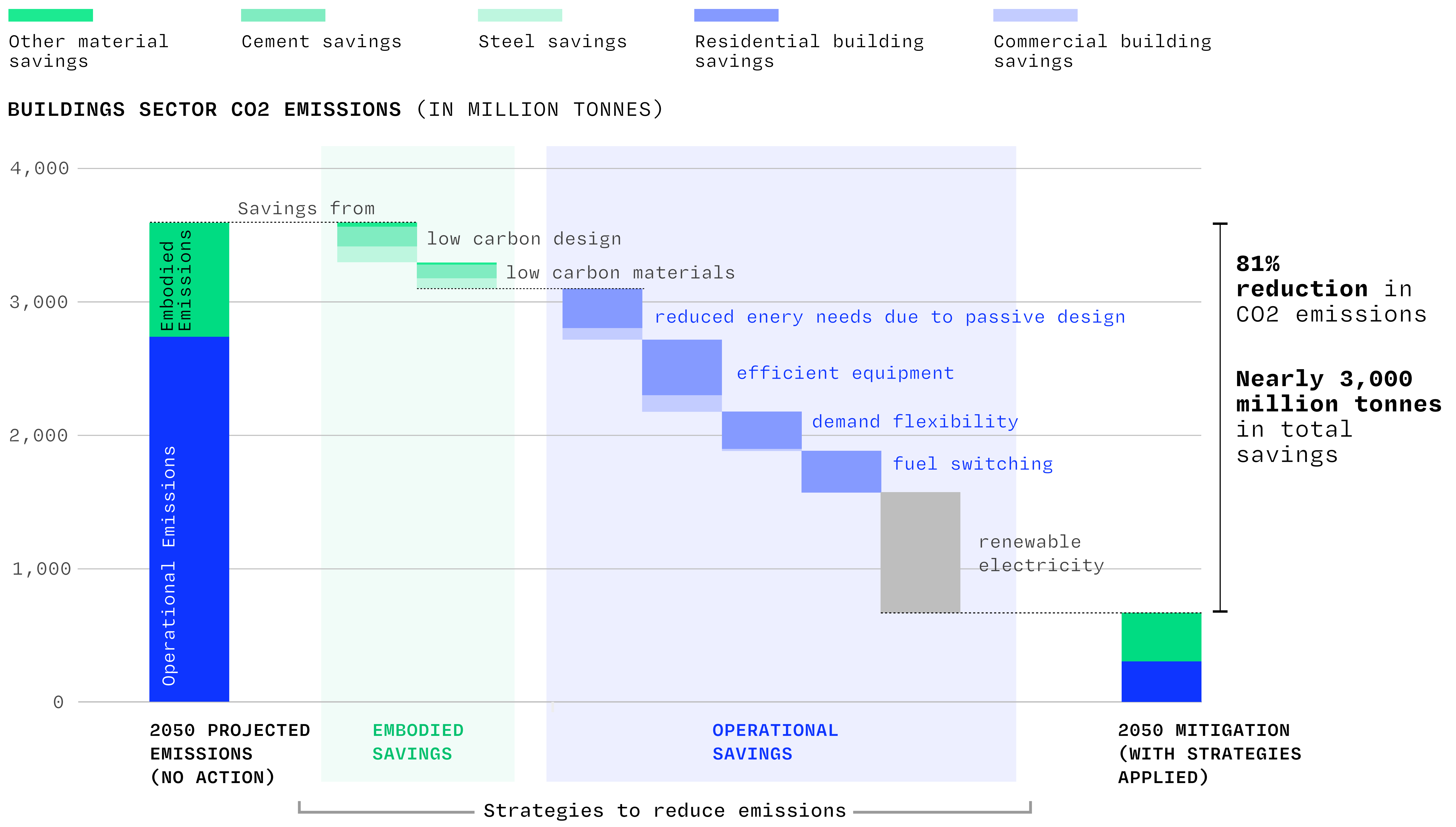
[Adapted from source: BS EN 15978[49], Rocky Mountain Institute (RMI)[50], Lawrence Berkeley National Laboratory (LBNL)[51] and IPCC report[52]]

The true need of the hour is a translation of knowledge about decarbonisation pathways into concrete business models and plans.

Reducing India's building sector's embodied and operational carbon requires a calibrated approach to decarbonisation instruments and solutions. These approaches must combine urban design interventions with decarbonisation technologies and strategies, be context-sensitive (catering to the vision of the city), balance cost with performance and offer possibilities for models of scalability.
In terms of solutions, low-carbon building design and materials, passive design solutions to reduce energy needs, energy-efficiency levels of equipment (or appliances) for thermal comfort, lighting etc., on–site and off–site renewable energy integration and energy saving behaviour by consumers are important levers to systematically reduce carbon. Government, businesses, and consumers will have their roles to play in this transformation.

These strategies require collective contribution from governments, businesses and consumers

EXHIBIT 7: The systematic deployment of available solutions and strategies is projected to put India's buildings sector on a net-zero pathway



[Adapted from source: Rocky Mountain Institute[53]]

2.4 Can the market value low-carbon?

It is difficult to deny that alternatives such as advanced insulation, energy-efficient HVAC systems, and smart technologies carry a higher price tag, and mainstream standards of sustainable buildings such as LEED often entail cost premiums. However, these cost analyses do not take into consideration the cost of carbon which is increasingly becoming the instrument of regulation for CO2 emissions. As carbon gets priced, it will pose a regulatory risk for real estate developers. Another distorting factor is the emphasis on upfront costs, rather than lifecycle cost of solutions. Moreover, due to advances in R&D and commercialisation of renewable technologies, the cost of technologies like solar photovoltaics has been dramatically dropping and today are cheaper or on par with conventional technologies.

What are the other advantages of investing in sustainable buildings? Low-carbon buildings can generate more revenues for real estate companies right from the word go. For instance, studies indicate a substantial rent premium attached to sustainability i.e. with LEED certification being a distinguishing criterion, many projects report a rent premium between 5 to 15 per cent.[54] According to Lasalle, the real estate asset values are also reported to increase by up to 25 per cent with sustainability credentials. As per a McKinsey report, the solutions that are cost competitive today and can become cost-competitive by 2030 can help us abate one-third of embodied carbon and about 70 per cent of operational carbon in buildings.[55] Put together, these factors signal the right market conditions for low-carbon transformation of India's built environment.

CHAPTER 3

Urban Scale: Build Resilience Against Heat

India's megacities support and sustain large populations, who are drawn to urban areas for the economic opportunities on offer. Cities need infrastructure, transportation services and buildings for residential and commercial purposes at a massive scale.

As part of its urbanisation push, India is going to add several industrial cities along the lines of Noida and Dholera, with 26 applications submitted by different state governments to the central ministries.[56] There is a real opportunity to relook at urban design interventions to ensure the cities deliver on the promises of liveability and sustainability, and are resilient to weather extremities.

As climate takes an uncertain form, our approach to urban design and planning must become more nuanced. A climate responsive urban form will pay close attention to variables like weather patterns, exposure to sunlight, wind speed, humidity, indoor and outdoor air quality etc. to inform the city layouts, land use policies, extent of green cover, and the scale and population of planned neighbourhoods.

The climate challenge has already prompted corrective responses by cities around the world. An important lever of action identified to reduce energy use in cities is the design of urban form itself, which supports walking, cycling and public transportation infrastructure, in addition to green spaces critical for healthy and elevated quality of life. C40 Cities, a global network of mayors spearheading climate action, reportedly had 74 member cities sign up for High-impact Accelerators since 2017. Chennai, for instance, restored 8 parks and 32 water bodies as well as developed vertical gardens under the Accelerator program.[57] Even though there are solutions being implemented in a piecemeal approach, the integrated urban design and development concepts are yet to be implemented on larger scales in India and across the world.

3.1 The power of innovative urban design

The Sant Antonio superblock is a 400m x 400m mixed use layout, consisting of a 3 x 3 grid system.

Several approaches to innovative urban design are available. As an example, the **Superblocks** concept implemented in the city of Barcelona is truly inspiring. Having been recognised as an effective climate solution by the United Nations, the idea has phenomenal scaling potential, especially in greenfield projects on redevelopment of urban areas. With the implementation of 503 Superblocks across Barcelona, Superblocks has now become an approach rather than a small neighbourhood overhaul plan. Impacts and benefits of the Superblocks approach have been quantified with renewed investigation into the applicability of the model to different cities and contexts, thereby emerging as a global best urban design and planning practice.

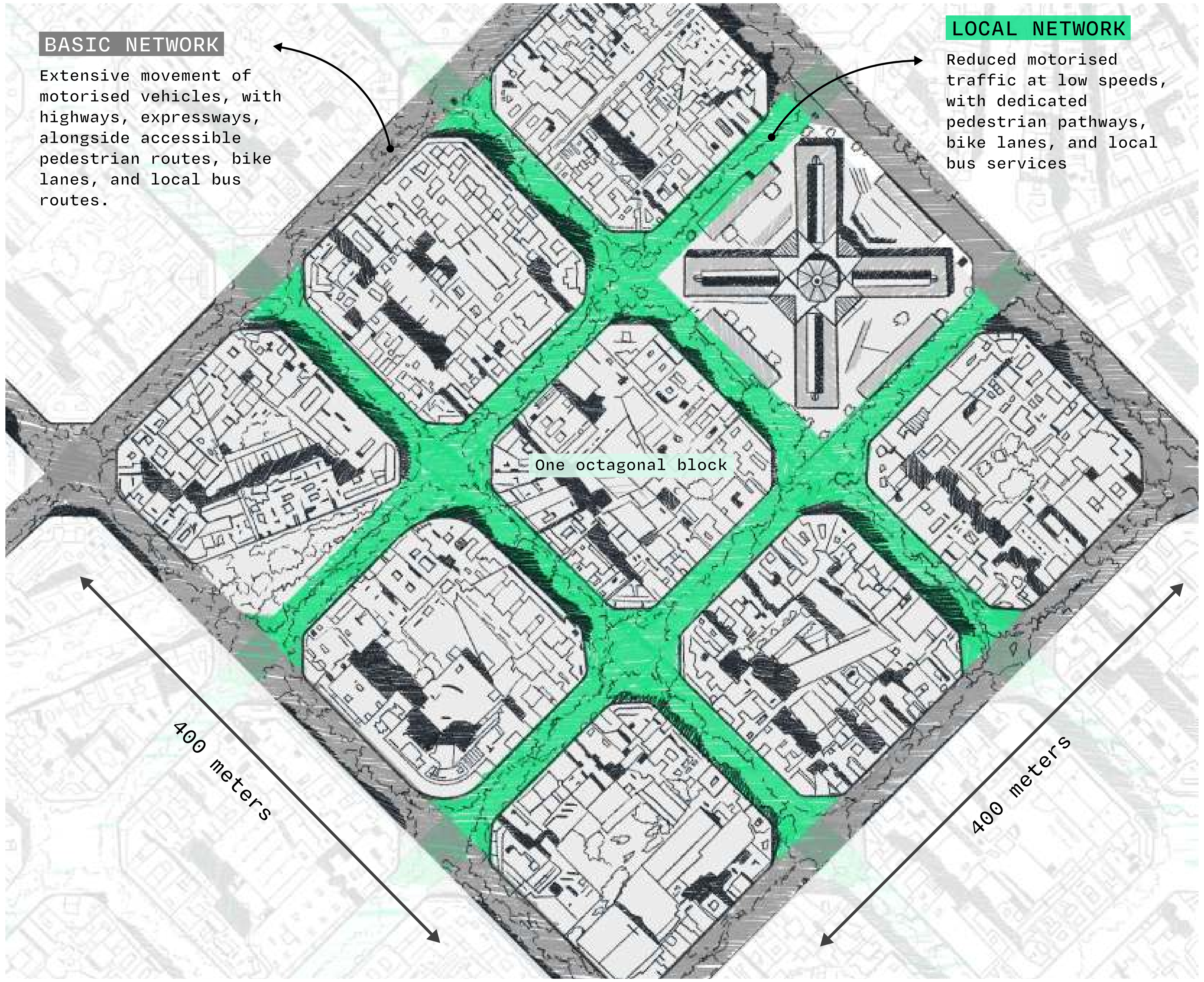
Superblock is a 400 m x 400 m mixed-use layout where the inner streets are closed off, while the traffic skirts around the buildings' outer perimeter. This design puts people in the centre (quite literally!) shielded from the vehicles and vehicular noise and pollution, thus enhancing safety, air quality and noise quality experienced by people. It also creates the opportunity to increase green cover available to the residents, thus improving the quality of community spaces leading to better community engagement.

Various studies have estimated the health, environmental and community benefits of the Superblock model. If implemented, the 503 superblocks will help reduce air pollution by 24 per cent[58], avoid 667 premature deaths annually[59], prevent 45 million euros in mental health costs annually[60], and increase the green cover by 5.67 per cent.[61] Given the substantial health and environmental costs avoided, the Superblock model not only pays for itself, but gives back much more!

Improvement in quality-of-life measures in Sant Antonio, a Superblock, 2 years after implementation[62]

Reduction in NO2 levels inside a Superblock	25%	**Reduction in PM10 levels**	17%	**Reduction in noise levels**	

EXHIBIT 8: **Barcelona Superblocks are more octagonal than square, allowing for smooth turning of traffic and further enhancing road safety.**



[Source: Author's analysis and illustration]

Barcelona Superblocks

Various studies have estimated the health, environmental and community benefits of the Superblock model. If implemented, the 503 superblocks will help:

Achieve a reduction in air pollution by	24%
Prevent premature deaths each year	667
€ Annual savings in mental health costs (in euros)	45 million
Expand green cover by	5.67%

[Image credit: Unsplash/ Logan Armstrong]

Given the substantial health and environmental costs avoided, the Superblock model not only pays for itself, but gives back much more!

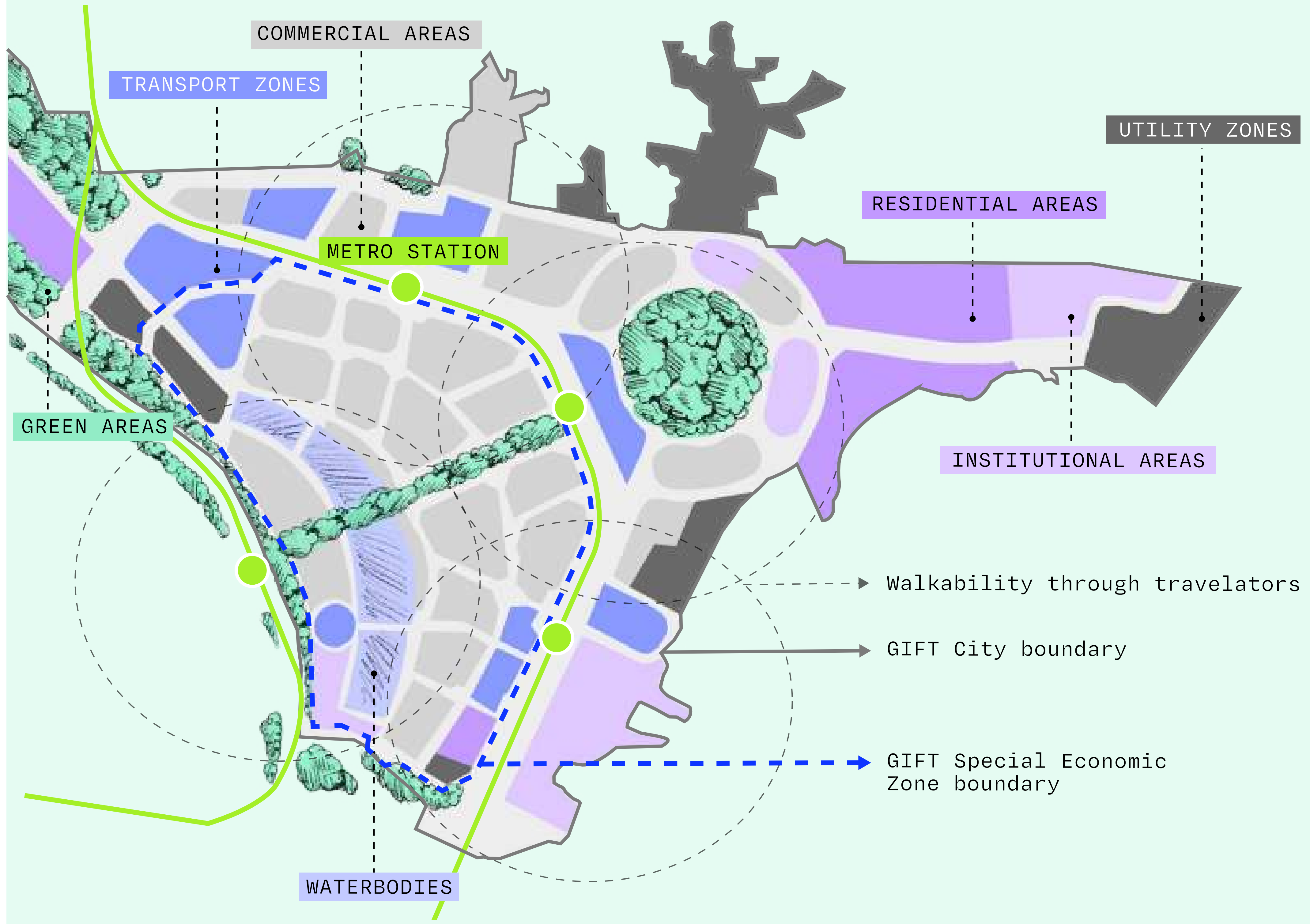
INDIA IN FOCUS - KEY LEARNINGS

Government of India has promoted development of such superblocks in the frameworks developed under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) and Smart Cities Mission initiatives, where Area Based Development projects (both greenfield, and redevelopment) were aimed at creating sustainable neighborhoods with better quality of life.

One recent example is the GIFT (Gujarat International Finance Tec-City) City in Gujarat, which is designed as a "walk-to-work" environment, integrating residential, commercial, and recreational spaces within proximity. This layout encourages walking and cycling, reducing the need for vehicular traffic within the city, and an integrated infrastructure and transportation access, which aligns with the superblock's aim to create pedestrian-friendly environments by minimising traffic.

Similar urban layout concepts have been implemented in the cities of Navi Mumbai, Dwarka sub-city in Delhi, Naya Raipur in Chhattisgarh, etc., where organised layout and extensive green spaces were integrated to offer a high quality of life.

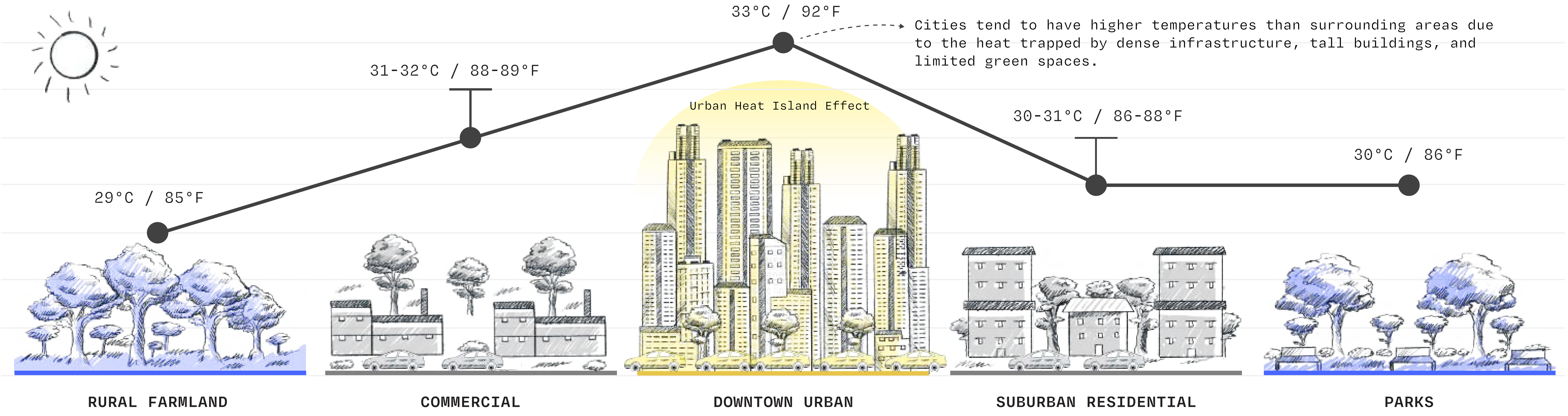
EXHIBIT 9: Accessibily and infrastructure in GIFT City, Gujarat



[Source: Author's adaptation of GIFT city map]

3.2 Solving for India's hot cities

EXHIBIT 10: Cities tend to have higher temperatures than surrounding areas due to the heat trapped by dense infrastructure, tall buildings, and limited green spaces



[Adapted from source: C40cities]

India's geographical location makes it one of the most heat-exposed countries in the world.

While we build cities, factors like building density, height and urban geometry affect the wind flow and influence how much heat gets absorbed and trapped within the urban atmosphere, a phenomenon termed as Urban Heat Island Effect (UHIE). Heat emissions from vehicles, industries and buildings add to the overall load of heat in cities. The decrease in green cover and water sources, both important natural regulators of temperature, contributes to worsening UHIE. During heatwaves, as the air temperature increases, the effect is exacerbated, which leads to the risk of health hazard, disruption of outdoor economic life and increased energy use for indoor thermal comfort.

3.2.1 Urban Greening

Heat has a multidimensional impact on city life, so responses to mitigate heat gain in urban developments must be mounted at multiple levels. The most well-known and cost-effective safeguard against rising heat is urban greening or green infrastructure of cities. Greenery regulates urban heat through evapotranspiration, and by reducing the surfaces exposed to sunlight. It is also increasingly promoted as a mitigation and adaptation strategy to deal with global warming. Improving the city's green infrastructure can assume several strategies.

Greening on the ground: The basic idea is to increase green cover close to the ground. This can take the form of park development, planting of trees, shrubs, grass, and conservation of natural urban forests such as Delhi's ridge areas. As per a review article published in Nature, this strategy can reduce the peak surface temperature by 2-9 degree Celsius.[63]

Greening of buildings: To reduce heat absorption by buildings, the surface area under direct sun's exposure must be reduced. It can take the form of green roofs and green walls/vertical greenery. These approaches hold the potential to reduce the surface temperature by almost 17 degrees Celsius.

EXHIBIT 11: **Green roofing in urban areas can significantly reduce heat gain by terraces**
[Image credit: Alamy/ Tony Giammarino]

However, the cooling potential depends heavily on scale (city or buildings), shape and size of green cover, plant selection and plant placement. To maximise mitigation benefits of urban greening, urban planners must use design optimisation strategies like intersperse green spaces through the city, allocate more space for trees than lawns and integrate multiple greening strategies where cooling requirements are higher.

3.2.2 Challenges in greening of buildings

Green roofs can be of two types: extensive and intensive. Extensive green roofs utilise a thin substrate layer (for growth of vegetation) with low level planting. Intensive green roofs have a deeper substrate layer to allow deeper rooting plants such as shrubs and trees to survive.

In terms of cost, extensive green roof systems perform much better. No structural enhancements for roofs are needed for extensive systems, making them suitable for retrofitting. Intensive green roofing systems, on the other hand, need structural design consideration due to extra weight imposed by intensive planting, making them a much more expensive solution for new developments and non-feasible as a retrofit solution in many cases.[64]

A leading practitioner of green roofing, Architect Salil Riswadkar states that his firm has completed roofing projects with an estimated cost of INR 7500 per square metre. The US EPA also estimated the cost of extensive green roofing systems to be in the range of $10 per sqm, and for intensive roofing systems in the range of $270 per sqm.[65] The same study estimated the maintenance costs to be in the range of $8 - $11 per sqm for either of the systems. The use of local materials in green roofing can drive down the costs by almost 50 per cent. However, these figures are old and a significant update in prices is expected.

The prices reflect the challenge of scaling the green roofing approach for thermal comfort. If these numbers hold, the upfront cost of installing a roofing project in an average 150 square metre terrace will be about INR 1.2-1.3 lakhs. The maintenance costs of green roofing are also substantial, the data for which is not readily available. With steep financial requirements, green roofing executed by professionals is still in the premium bracket. Other factors that impact the quality and sustenance of Green Roofing are as follows:

a. **Substrate depth** plays a huge part in the success of a green roof project. An incorrect level of substrate depth can lead to drying out of plants when exposed to the sun. The required substrate depth entirely depends on the vegetation specified. For example, Low growing sedum will need a shallow, and porous substrate, while Wildflowers will require a deeper substrate of around 100-150mm. Intensive green roofs will require even greater depths of around 300-450mm which can go up to 800mm.

b. **Irrigation** requirements typically vary from extensive, semi-extensive, and biodiverse green roofs to intensive green roofs. Intensive green roofs will require a permanent irrigation system to nurture deeper growing mediums, and therefore higher irrigation maintenance.

c. **Roof drainage** is another important factor. Impaired drainage is a common issue leading to plant loss, which usually happens when an unsuitable membrane is used or wrongly installed. To protect the roots of green roof, the drainage membrane should let water to drain away safely. Therefore, it is important to check for blockages and sufficiency of the membrane.

ES
1
2
3
4
5
6
7
8

EXHIBIT 12: A top view of Green Corridor in Medellin, Colombia
[Image credit: Alcaldia de Medellin / Mayor of Medellin]

CASE 1

Greening at city scale: Green Corridors of Medellin

Medellin's Green Corridors have become a symbol of adopting nature-based solutions to solve for heat and air quality. Started with a plan to build 30 (12 waterways, 18 roads) interconnected Green Corridors, the $16.3 million 'Greener Medellin for you' programme has succeeded in planting more than 893,000 trees and about 2.6 million other plants by 2021.[66] The species of trees and plants have been carefully chosen for their functional properties and potential to support urban biodiversity. Today the Green Corridors have given Medellin a reduction of 2 degree Celsius in average temperatures, an improvement in air quality through PM2.5 absorption, skills, and employment to more than 75 underprivileged people for gardening and maintenance services, and an estimated absorption of 160,787 Kg CO_2 per year by the new vegetation growth in just one corridor.[67] The programme won the Ashden Prize in 2019 in the category of Cooling for People.

Medellín's Green Corridor **2021**

Planted	893,000+ trees 2.6 million other plants
Temp reduced by	2 °C
Estimated Absorption per year	160,787 Kg CO2

Implementation of the programme offers several takeaways. The programme was able to raise funds for development through people's selection of projects, known in Colombia as 'participatory budgeting,' which ensured complete buy-in from the local population. However, Green corridors need significant upkeep and maintenance with an estimated budget of $625,000 per year. There is an important lesson for policymakers and city representatives that Green Corridors are like any other urban infrastructure requiring operational expenses for longevity and effective services. Finding innovative ways to secure funds for these expenses should also be a part of the plan for long term gains.

Several cities in India have earned the mantle of 'green city' due to high tree cover and green belts and corridors. Designed by the architect Roger Anger, Auroville in Tamil Nadu features a 2.5 km green stretch which helps to keep temperatures in check as well as promote biodiversity. Chandigarh, Punjab has an 8 km long linear park called 'Leisure Valley' that runs along the city's centre, in addition to green areas in every neighbourhood. Chandigarh's green areas continue to grow, and the city today has around 1,807 municipal parks and 41 per cent tree coverage.[68] Urban greening opportunities are still available for many smaller and tier-2 cities in India which are yet to see rapid growth. In view of its impact, the Town and Country Planning Department of the Government of India had notified Urban Greening guidelines in 2014. Also, the Ministry of Environment, Forests and Climate Change launched the Nagar Van Udyan Program aimed at developing 200 city forests across India.

EXHIBIT 13: High heat-gain areas such as metro stations, pavements and bridges have been targeted under Green Corridors.

[Image credit: Alamy/Long Visual Press]

INDIA IN FOCUS - KEY LEARNINGS

Climate Smart Cities Assessment Framework (CSCAF) has been launched by the National Institute of Urban Affairs, Ministry of Housing and Urban Affairs (MoHUA) to track the progress of climate actions and estimate the effectiveness of solutions implemented in 126 cities (100 cities under the Smart Cities Mission and 26 other interested cities) across India. In CSCAF 2.0, conducted between September to December 2020, under the Urban Planning, Greenery & Biodiversity category, cities like Indore, Surat and Visakhapatnam have shown exemplary performance in creating and maintaining green spaces, water bodies and improved disaster resilience measures. Nearly all the cities are performing well in terms of the extent of green cover and water bodies present in the city. However, the evaluation indicates a gap in implementation of conservation actions and maintenance of these areas. Cities need to strengthen efforts through regular mapping, monitoring, and targeted budget allocation to address these gaps. On the other hand, most cities - both under the Smart Cities and AMRUT Missions - are presently exploring interventions in urban biodiversity, disaster resilience and climate action planning at the local level. While recent guidelines from the Government of India, State Governments and the NGT have been instrumental in raising awareness and initiating the discourse on these aspects, cities are at a nascent stage of setting up institutional structures, planning and implementing measures.

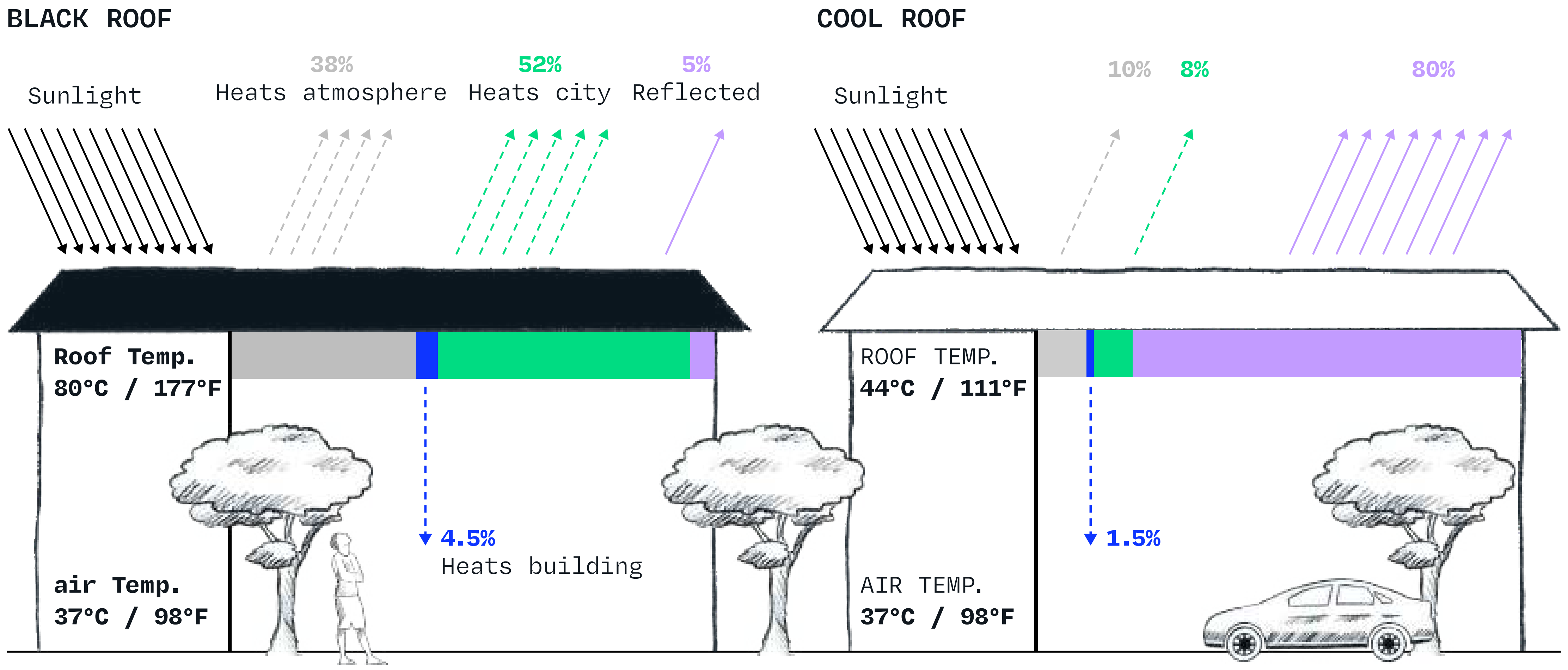
ES 1 2 3 4 5 6 7 8

3.3 Cool rooftops

Cool surfaces are a type of solution to decrease heat gain by the built environment. Conceptually, cool surfaces are made of materials that are designed to reflect more sunlight than a conventional roof, thereby absorbing less solar energy. Cool surfaces are measured by how much sunlight they can reflect (solar reflectance) and how much heat they can emit (thermal emittance).

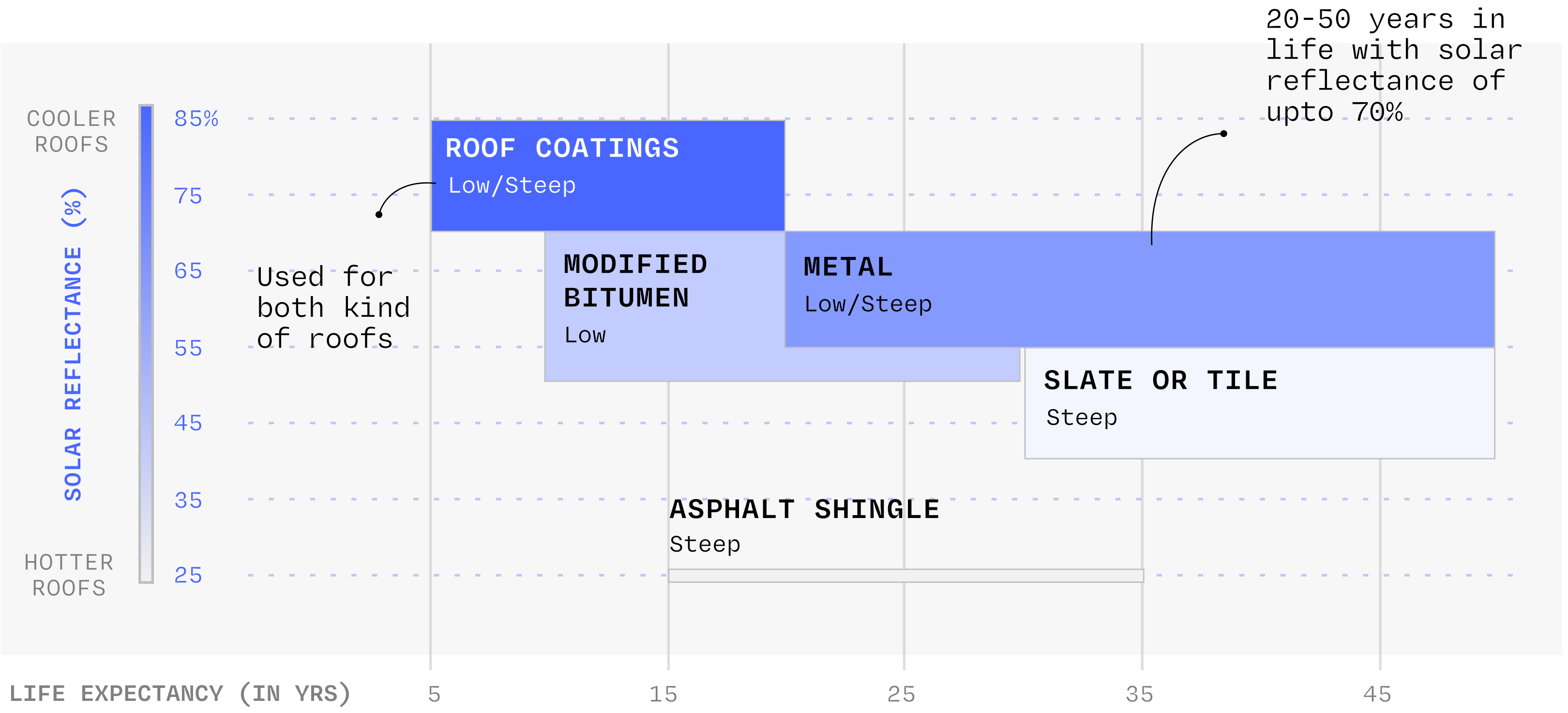
Cool surfaces are easy to install and maintain, making them a preferred solution for informal housing settlements as well. This class of solutions is known to provide benefits, both at the household and neighbourhood level. For households, it provides thermal comfort, reduces the need for air-conditioning and leads to energy and cost savings. At the neighbourhood scale, cool surfaces help in reducing the urban heat island effect, and mitigating peak power energy demand. Cool surfaces can be installed in two modes: (1) Cool roofs, and (2) Cool pavements. There are several kinds of cool roofs with varying solar reflectance index, cost, and durability. Some of these options available and used in India are discussed below.

EXHIBIT 14: Cool roofs vs black roofs: the albedo effect



[Adapted from source: C40cities.org n.d.]

EXHIBIT 15: Cool roofs are available in different materials, costs, and durability range



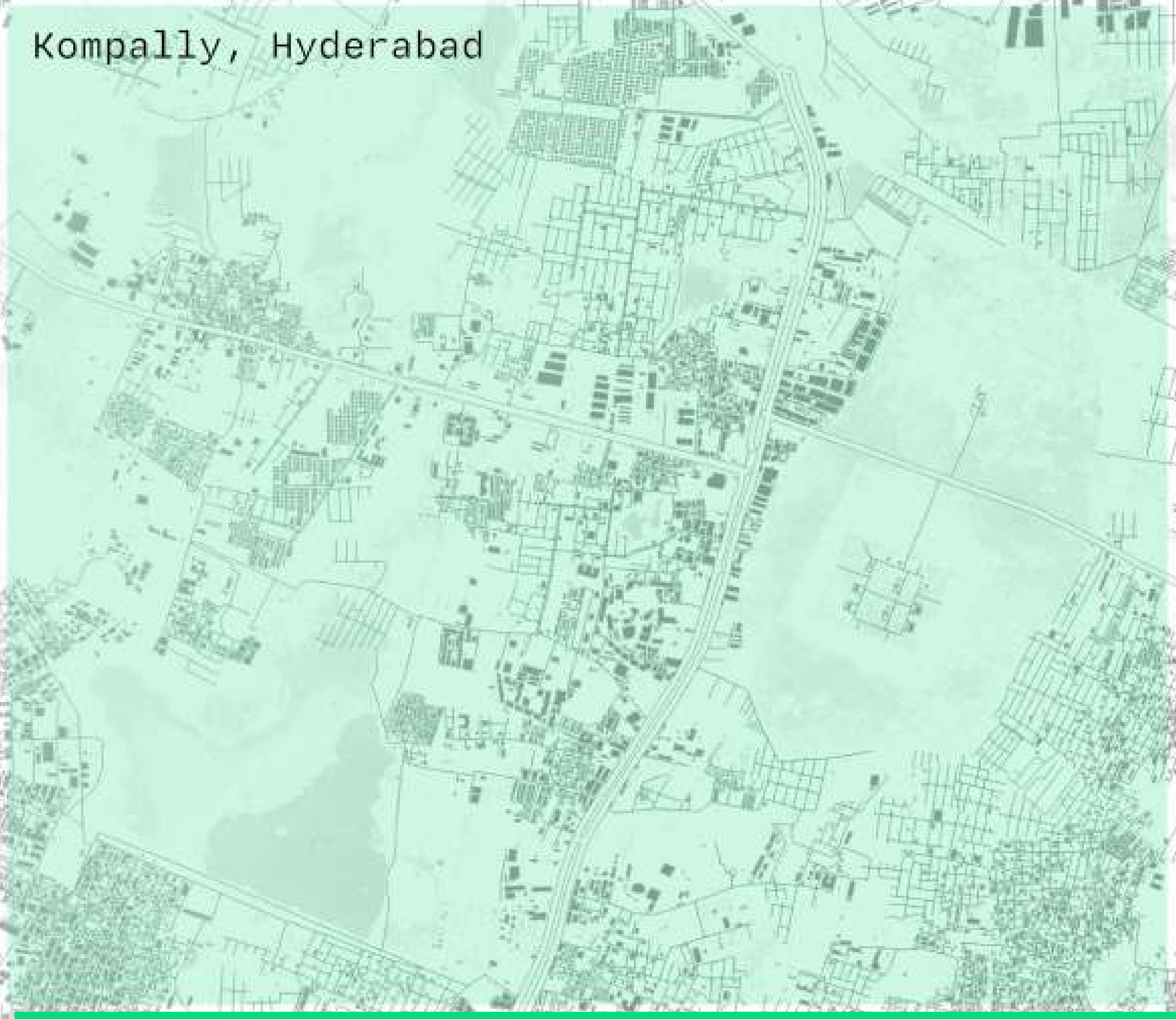
[Source: Author's adaptation from Shakti Sustainable Energy Foundation[69]
Note: The solar reflectance values have been sourced from Coolcalifornia.org.]

Depending on the choice of cool material, cool roofs can be a very affordable option. As a low-cost option to provide thermal comfort, it has found favour as a solution in contexts where other solutions are difficult to apply, such as slums, informal housing, temporary shelters etc. The ease of installation, short payback periods and easy maintenance are all desirable qualities that make cool roofs a fit case for scaling.

EXHIBIT 16: The quick payback periods make cool roofs an ideal solution for low-cost dwellings

COMMON ROOFING MATERIALS	COOL OPTIONS	PAY BACK
Cement Roof	White Cement	<1 year
Tiles	White/Light colour tiles	Negative to 1 year
Industrial Roof	White/Light colour coating	3-4 years
Metal Roof	White paint/coating	<1 year

[Source: IIIT Hyderabad[70]]



CASE 2

Telangana's Cool Roof Policy

Prior to the launch of the Cool Roof Policy, Telangana experimented with a cool roofs pilot in 2017 in collaboration with Natural Resources Defence Council (NRDC), Administrative Staff College of India (ASCI), International Institute of Information Technology- Hyderabad (IIIT-H) and Plaksha University. With implementation efforts led by Telangana's Municipal Administration and Urban Development (MA&UD) and Greater Hyderabad Municipal Corporation (GHMC), the pilot focussed on generating awareness about the solution and different modes of installation in low-income settlements.

For the pilot, 25 city roofs in one low-income neighbourhood were recruited, with an additional 15 households serving as a control group. Using inputs from Hyderabad officials, the community members partnered with ASCI, IIIT Hyderabad, and NRDC to design, install and monitor results. A high-density polyethylene cool roof membrane, Tyvek, was provided by Dupont India for the pilot. The project team also studied alternative coatings as well to compare performance. The results showed that the indoor air temperature was lower by an average of 2°C (3.6°F) in the homes with cool roofs compared to similar homes without cool roofs. It was corroborated by a resident feedback survey, with 76 per cent of the trial group showing enthusiasm.

EXHIBIT 17: Mosaic roof installation in Kompally, Hyderabad, Telangana

[Image credits: Agha Khan Agency for Habitat]

The encouraging results of the pilot led to the launch of Telangana Cool Roof Policy in 2023. It aims to cover 300 square kms of area over the next 5 years. The policy mandates cool roofs for all the government, non-residential, and commercial buildings. In addition, the residential buildings with a plot area of 600 sq. yds. or more are also mandated to have cool roofs, with smaller residential buildings having the option to voluntarily build them.

Telangana's Cool Roofs Policy focuses on implementing four key objectives: 1) drive rapid state-wide adoption of cool roofs, 2) create a robust institutional framework for implementation, 3) identify financing frameworks and undertake outreach to spread awareness on cool roofs and 4) support workforce development and training programs for cool roof installations.

While the Cool Roof Policy marks a significant achievement, the focus is now shifting to effective implementation. The adoption of cool roofs in government low-cost housing, including existing structures, could be financed through government budgets and incentive mechanisms, and can also be integrated into procurement criteria. The policy aims to achieve projected savings of 600 million Units (GWh) of electricity annually after five years.

"With this Policy we aim to be an eco-friendly state with reduced dependence on energy consumption for cooling".

- Minister K. T. Rama Rao

EXHIBIT 18: Telangana has set aggressive targets to scale up cool roof programme implementation

YEAR	HYDERABAD COOL ROOF AREA TARGETS (IN SQ.KM)	REST OF TELANGANA COOL ROOF AREA TARGETS (IN SQ.KM)	ANNUAL TOTAL TARGET FOR TELANGANA (IN SQ.KM)
2023 - 2024	5	2.5	7.5
2024 - 2025	20	10	30
2025 - 2026	40	20	60
2026 - 2027	60	30	90
2027 - 2028	75	37.5	112.5
Total aggregated area by 2028 - 2029	200	100	300

[Source: National Resource Defence Council, India[71]]

EXHIBIT 19: Cool roof installation process can be community administered supported through training and capacity building

[Image credit: National Resource Defence Council, India]

CHAPTER 4

Material and Design Scale: Tackling Embodied Carbon in India's Built Environment

Embodied carbon is a less talked about problem when it comes to building sector emissions. Without appropriate strategies adopted in the early phases of project development, the buildings are locked in with enormous amounts of embodied carbon for rest of their life cycle.

Construction industry is responsible for a significant portion of global CO_2 emissions

Emissions from materials and construction processes	~13%

Low-carbon building development approach is increasingly critical as the construction industry is responsible for a significant portion of global CO_2 emissions – approximately 13 per cent from materials and construction processes.[72]

The embodied carbon to completion i.e. upfront embodied carbon, depends upon the design of the building, choice of materials and construction technology, manufacturing process of building materials and primary energy source, and the local availability of such materials. The operational carbon emissions can be reduced through better appliances and substitution of fossil fuels with renewable energy sources but reducing embodied carbon of buildings across their lifecycle is still a complex problem for the construction industry to solve. Addressing the embodied carbon emissions will take effort from a variety of stakeholders involved in the construction sector across different stages of a building's lifecycle as explained in chapter 2. Two kinds of strategies are available to building sector stakeholders for addressing embodied carbon: 1) Low-carbon materials for construction, 2) Low-carbon building design choices.

4.1 Materials choices for low-carbon buildings

The choice of building materials during design and construction of a building significantly influences the performance of the building on various sustainability parameters.

Understanding how material choices impact sustainability is crucial for architects, builders, and policymakers aiming to reduce the environmental impacts of the construction industry. Material selection affects various aspects of a building's life cycle, from its resource and carbon footprint to its longevity and overall impact on the comfort and health of occupants.

A study conducted for three different affordable housing projects located in Rajkot highlights that concrete and steel contribute nearly 60 to 90 per cent to upfront embodied carbon, followed by the walling materials contributing about 10-25 per cent.[73] Another study conducted for three different residential building projects in Bengaluru establishes that the share of embodied carbon to the whole life carbon footprint of these buildings lie in the range of 29-43 per cent. It also highlights that the contribution of concrete, steel, and masonry wall and plaster account for nearly 95 per cent of total upfront embodied carbon emissions.[74] The evidence is clear therefore that concrete and walling materials are the two strategic areas where interventions can make a huge impact. Steel decarbonisation will largely come from utilisation of carbon capture, utilisation and storage and increasing use of renewables. However, these innovations are beyond the scope of construction ecosystem and will not be discussed here.

1. Low-carbon concrete emissions through LC3

Concrete is the primary material used in construction of buildings and infrastructure. To decarbonise concrete, one will have to start by decarbonising different constituent materials that make up concrete. One of the most important components of concrete is cement which accounts for about 75-80 per cent of concrete linked emissions. Therefore, by reducing carbon emissions linked with cement, one can manage a significant part of embodied carbon in the buildings sector.

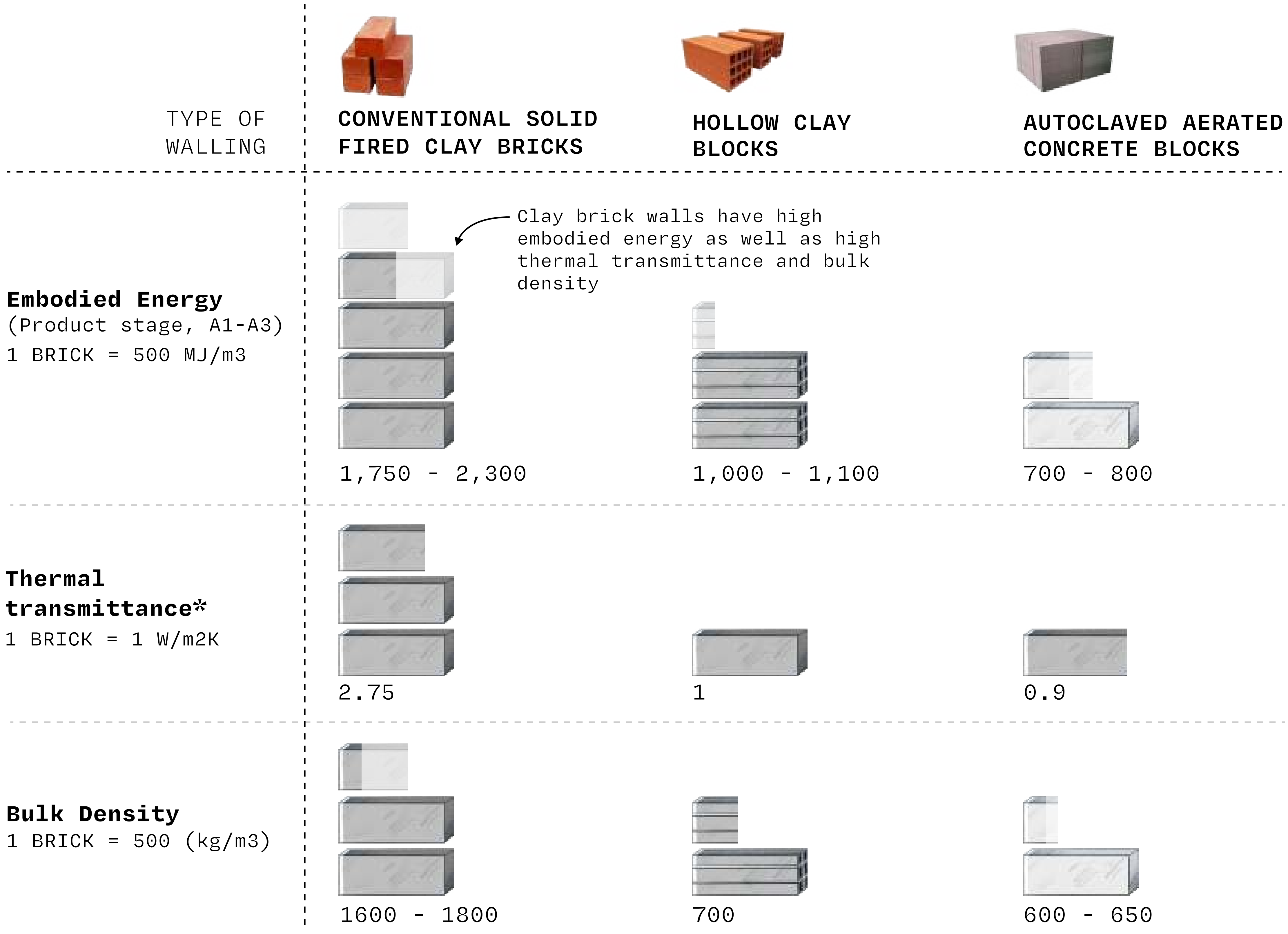
Cement manufacturing is an emission intensive process. It is also estimated that nearly 56 per cent of the total 0.66 tonnes of CO_2 per tonne of Ordinary Portland Cement (OPC) produced is due to the calcination of limestone in the kilns, 32 per cent due to the combustion of fuels for process-heating applications, and about 12 per cent due to the electricity used for manufacturing.[75]

In cement manufacturing, clinker is an intermediate product produced by sintering and cooling ground limestone. The per centage of clinker in cement is known as the clinker factor. The OPC has a clinker factor of about 90-95 per cent. This is where the opportunity lies: One can cost-effectively achieve low-carbon cement by increasing the use of clinker substitutes such as fly ash, blast furnace slag, volcanic ash etc.and achieve a lower clinker factor. Although clinker substitution is practiced widely, as fossil fuels are phased down, substitutes like fly ash will be less and less available.

Producing cement with less CO_2 emissions is technically challenging because 56 per cent of emissions stem from the decomposition of limestone at 1450°C. LC3 or Limestone Calcined Clay Cement is a promising and cost-effective technical solution to deal with this problem. A 50 kg bag of LC3 is a pre-mix of 50 per cent OPC cement blended with 50 per cent of substitute materials, namely, 15 kg of calcined clay, 7.5 kg of uncalcined limestone and 2.5 kg of gypsum.[76] LC3 has lower emissions because clay calcination occurs at lower temperature (800°C) and there is no decomposition of limestone as the limestone in LC3 is mixed without burning. LC3 therefore can reduce about 40 per cent of emissions associated with cement production. LC3 can be widely applied around the globe; suitable clays are available almost everywhere, and a production plant requires much lower investments and operating costs than an OPC plant; it is also a much more affordable alternative to carbon capture and storage technologies (CCS).

AAC blocks appear to be the most environmentally efficient and thermally effective option among the three

EXHIBIT 20: The alternatives to conventional walling material like bricks must be analysed across several parameters



[Source: Author's analysis and illustration]

(Note: Thermal transmittance is a function of thermal conductivity and thickness of the material. These bricks and blocks are available in the market with varying thickness values. For comparison purposes, 200 mm thickness is considered for all the materials).

2. Low-carbon walling materials

From the carbon footprint perspective of the materials used in a building, materials used in the construction of walls, roofs, and other structural elements such as beams, columns, and bars have the largest influence on the embodied carbon and operational carbon (thermal properties of the building envelope) of the building. To effectively reduce the whole lifecycle carbon footprint of a building, use of sustainable building materials with following properties are recommended:

a. **Low embodied carbon materials:** materials having low embodied carbon and manufactured locally using local resources (to reduce transportation)

b. **Low thermal conductivity materials:** Thermal conductivity of a material influences the rate of heat transfer through the material. Higher the conductivity value, higher will be the heat transfer rate through the material. Low conductivity materials help reduce the heat gains inside the building through the building envelope. This report[77] provides a comprehensive database of thermal properties of various walling materials and walling technologies, and can be used by the building sector practitioners in selection of appropriate materials. In addition, additional insulation (insulation materials like Extruded Polystyrene, Polyurethane Foam, etc.) can also be applied in walls and roof to improve the thermal performance of the envelope.

c. **Low bulk density materials:** Bulk density of materials impacts the carbon footprint of a building in two ways. Low density materials help reduce the dead weight of the buildings and thereby reduce the quantity of concrete and steel required in the structural elements. This results in lower resource and embodied carbon footprint of the building. Low density walling materials also have lower thermal conductivity, and thus, help reduce the heat gains through the building envelope. A correlation has been established between the bulk density and thermal conductivity of materials though lab testing of several samples collected from across the country.

There are several examples of building materials that perform well on all three parameters discussed above. This is demonstrated below with the example of two such masonry walling materials - hollow clay blocks and auto-claved aerated concrete (AAC) blocks, and its comparison with the conventional solid fired clay bricks.

An analysis conducted to estimate the impact of replacing conventional solid fired clay bricks with hollow clay blocks on the concrete and steel consumption and embodied carbon of a four-storey residential building provide the following results[78]:

▼ **Reduction in concrete use**	~20%
▼ **Reduction in steel use**	~30%
▼ **Reduction in the upfront embodied carbon**	~27%

3. Recycle and reuse of construction and demolition (C&D) waste

The end-of-life embodied carbon constitutes the demolition waste and emissions arising from its transport and processing, which can amount anywhere between 3-15 per cent. In this context, recycling concrete is another lever available to building developers to reduce embodied carbon emissions. Recycled concrete aggregates can be made after pulverising concrete debris from construction and demolition (C&D) waste, which can be suitably used as substitute for natural aggregates. The entire process involves lower CO2 emissions over the product lifecycle across the value chain. In India, Godrej & Boyce has set up a state-of-the-art manufacturing facility for Recycled Concrete Materials in Mumbai, with capacity of recycling 300 tonnes of concrete debris per day.[79] Contrary to general perception, recycled concrete products are at par with the virgin product and meets all performance parameters and compliance standards.

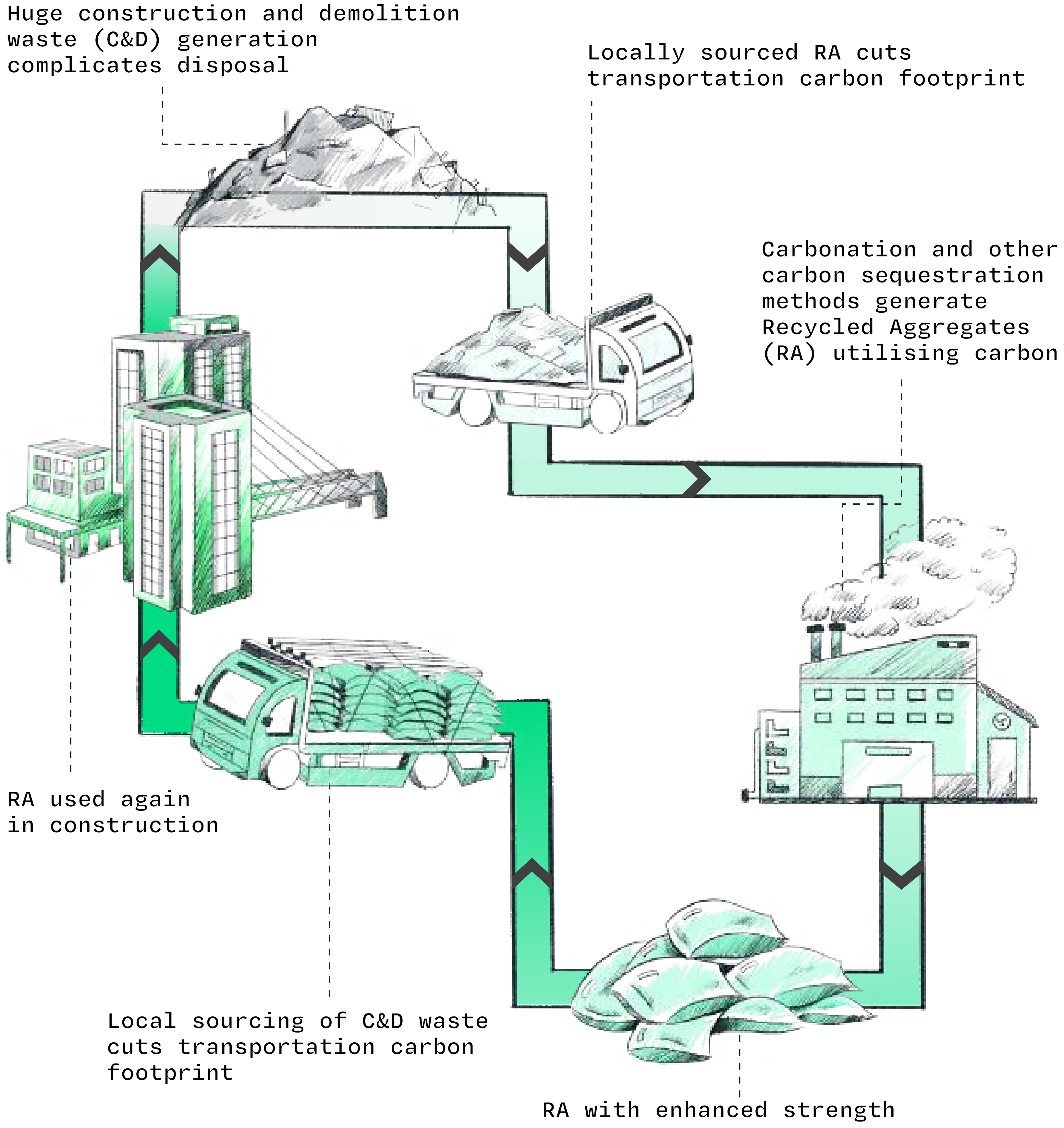
To promote use of C&D waste, Ministry of Road Transport & Highways (MoRTH) has been working on the guidelines for value engineering during preparation of feasibility reports of proposed highway projects. Wider acceptance of this technology by the construction ecosystem needs a mindset change. It can be a game changer if C&D waste recycling plants becomes a regional play.

Scaling low-carbon material adoption

In addition to the carbon footprint criteria, there are other sustainability and business parameters that substantially influence the choice of materials, especially in the case of large building projects of organised developers. Other sustainability parameters include a) Impact on natural resources and its depletion, b) Impact on indoor air quality, c) Waste generation during construction and end-of-life of building, and recyclability and reusability, and d) Longevity and maintenance requirement. Business and execution related parameters include a) Ability of the material to aid in faster construction (reduced construction time significantly influences the economics of a project), b) Ability to provide better control over the quality of construction, and c) Ease of bulk procurement.

From the previous example, it is evident that the choice to use an alternate material, hollow clay blocks or AAC blocks as substitutes of fired-clay bricks, for the construction of walls can be advantageous on multiple sustainability and business parameters. However, in the case of monolithic concrete construction (becoming prevalent in large construction projects), while it is excellent on parameters like faster construction, quality of construction, etc., it has a negative impact on thermal comfort because of its higher thermal conductivity.

EXHIBIT 21: Framework for carbon compensation for promoting circular economy



[Adapted from source: AI-based carbon emission forecast and mitigation framework using recycled concrete aggregates: A sustainable approach for the construction industry[80]]

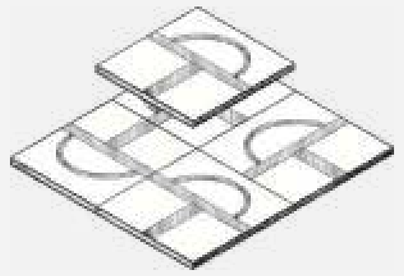
ES
1
2
3
4
5
6
7
8

It is important to undertake a comprehensive comparative analysis to understand the impact of different material and construction technology choices on various sustainability and business parameters over the life time of the building, and strike a balance between sustainability and business parameters.

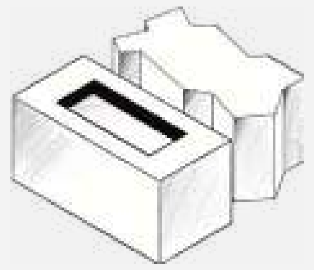
Similarly, to promote higher uptake of recycled products made using C&D waste in the construction sector, there needs to be more emphasis on development of public procurement policy, lowering GST slab rates for recycled products, incorporating new guidelines in relevant building design codes and standards to encourage use of C&D waste right at the design stage of any project. Incentivizing all stakeholders involved in C&D waste management would provide financial benefits for better implementation of C&D waste rules and framework.

Low-carbon material innovation

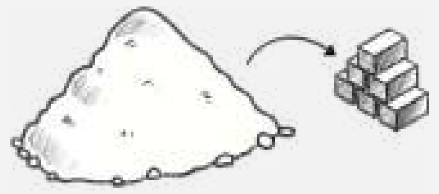
To deal with the challenges associated with underwhelming uptake of low-carbon materials, technology and business innovation is must as it can create technical evidence for its use in larger and bigger projects, which can further create economies of scale needed to bring the cost down. Material libraries and databases can also help in informing and stakeholder choices.[81] Several start-ups in India are experimenting with low-carbon material offerings with potential to scale up in the future.



CarbonCraft Design is a Hubli based design and material innovation company started in 2019. Their primary innovation is a commercially available tile.

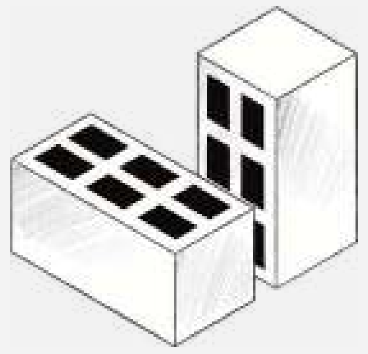


RecycleX is a Bharuch based startup that makes products manufactured out of industrial waste such as fly ash bricks and paver blocks.

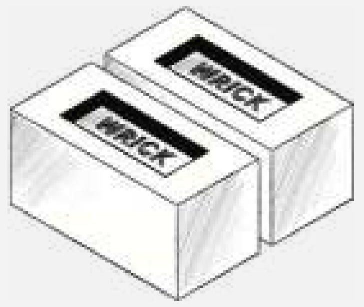


Saltech Design Labs is a circular tech company transforming waste into alternate materials for construction and infrastructure applications while cutting GHG emissions, enhancing resource recovery and promoting sustainability.

Terracarb is a DPIIT-registered deep science Indian start-up and South India's largest manufacturer of industrial graphene additives for concrete, conductive inks, epoxy coatings, energy storage, lubricants, rubber, biofilters and related applications.



GreenJams is a startup aimed to build better buildings with carbon negative materials and solutions. They create carbon negative concrete that combines processed crop fibres with a mineral binder to not only build beautiful and durable structures but also leave behind a better world for the next generations.



Angirus is revolutionising Indian brick industry by transforming non-recyclable waste into functional, eco-friendly building materials such as bricks ad paver blocks. Leveraging their green waste management technology, they aim to bridge the gap between brick industry and modern sustainability needs, offering a cleaner, more sustainable alternative that reduces both solid waste and brick kiln pollution.

4.2 Lean and passive design approaches for buildings

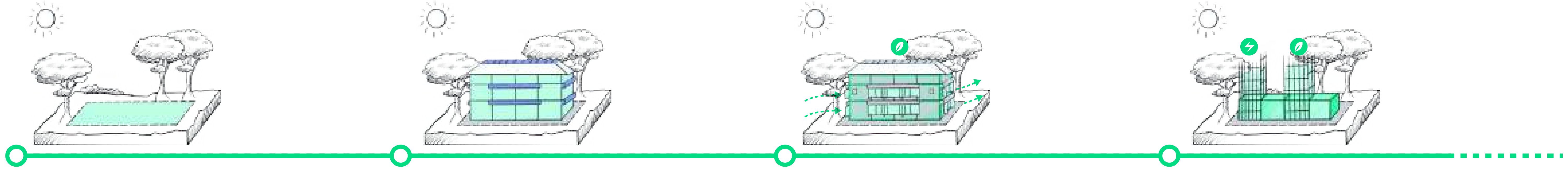
Reducing the whole life cycle of embodied carbon is not just about selecting a high-performance low-carbon construction material or appliances.

It must follow a holistic vision and process, focused around adopting decarbonisation, resilience, circularity, and equity. The low-carbon development demands effective collaboration across architecture, engineering, and construction, during every step in the life cycle of the building construction and operations. This practice is often termed as integrated design approach.

The integrated design approach for low-carbon development requires intensive data collection and analysis by the involved professionals, like site climate analysis, site and building design performance analysis, thermal and energy performance analysis, structural analysis, embodied carbon analysis, etc.

A comprehensive blueprint with the right sustainable materials and construction practices is developed at the end of the integrative design process. The figure below shows different stages of the building design process and the carbon reduction methods that can be integrated into building design and construction. Also, a detailed life cycle cost and carbon accounting is an essential component of the integrated design approach, after completion of technical analysis of low-carbon development strategies.

EXHIBIT 22: Carbon reduction strategies across different design stages of a building project



DESIGN PHASE	PRE-DESIGN	SCHEMATIC DESIGN	DETAILED DESIGN	CONSTRUCTION
CARBON REDUCTION STRATEGY	Climate responsive site planning Building morphologies to meet lean design concepts	Adopt solar passive building envelope, and low volume same function concept for spatial design Create bespoke green solutions portfolios through D&E firms	Integrate high thermal performance materials for components and opt for low-embodied carbon materials Opt for low embodied carbon materials	Activate D&E and modular construction firms to minimise waste, as well as firms that provide on-site equipment charging services

[Source: Author's analysis and illustration]

Lean Design Principles

The lean design principles underline the efficient material usage and reduce the overall volume of buildings. By designing more efficient layouts, architects can decrease the quantity of construction materials needed, which in turn reduces both embodied and operational carbon emissions. Lean design helps reduce both the embodied carbon and operational carbon emissions in the building.

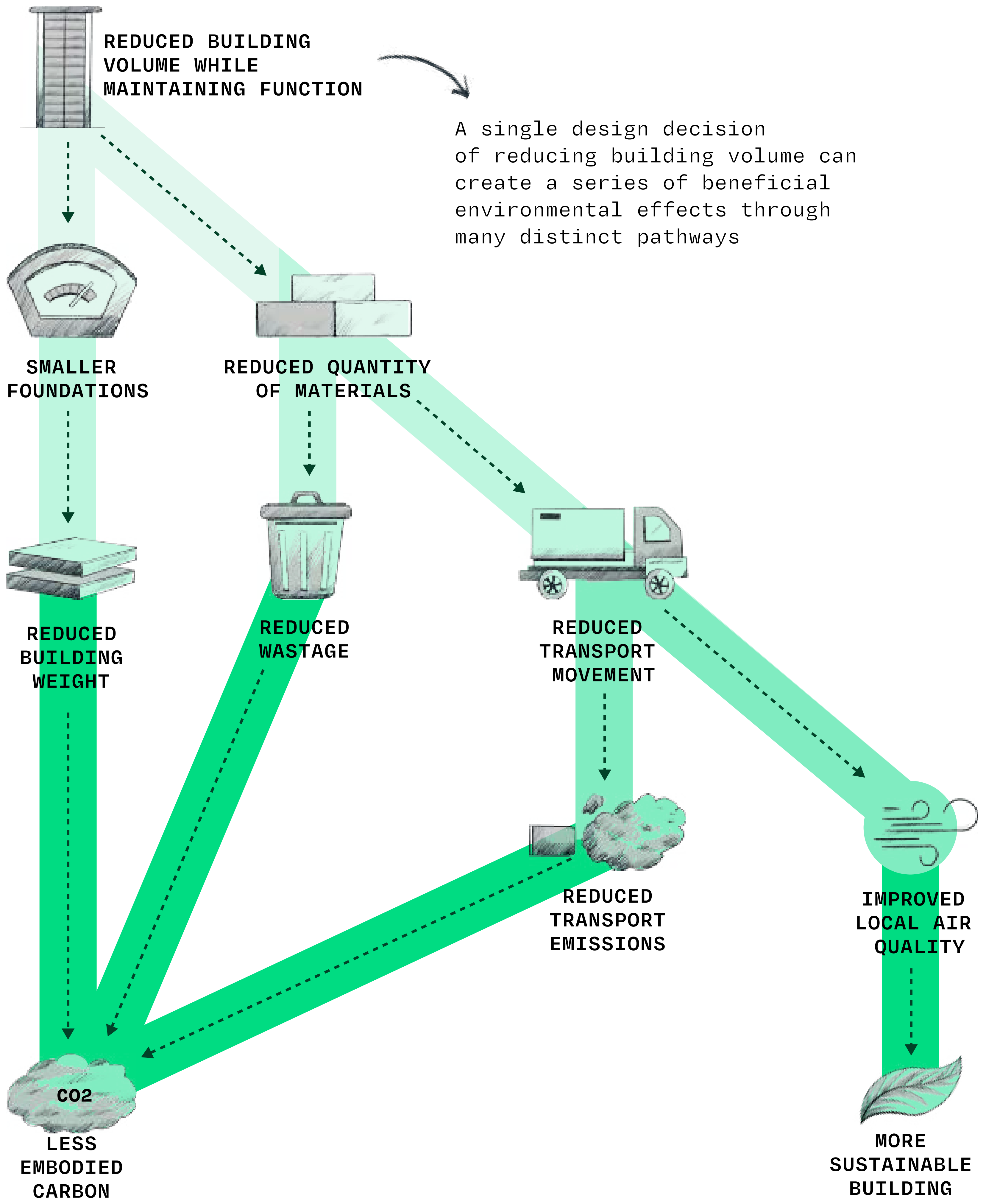
The lean design principle promotes lesser construction volume with same function, which can be achieved by the following strategies: a) Reduce form factor to optimise the surface area exposed to external environment relative to their floor area, b) Improve the optimisation factor of steel in the structural elements to reduce the need for steel, c) Reduce the thickness of concrete slabs to optimise the quantity, and d) Balance the insulation thicknesses of walls, floors and roofs according to the exposed surfaces.

Reduction in the volume of building materials decreases the overall weight of the structure. It lessens the load on the foundations, which enables further decrease in the materials required for substructure. Lean design emphasises optimal sizing, eliminating unnecessary redundancies and excess capacities. The reduction in the volume further reduces the energy needs for transportation and the requirement of packaging used with the materials.

The lean design can help reduce the overall project carbon emissions by reducing the need for higher ventilation rates and lighting, which in turn, lessen the space required for electrical and HVAC utilities.

With the use of Building Information Modelling (BIM), the exact quantities of materials required can be estimated, which limits over-ordering to site, and aids sustainable construction. Using a DfMA (Design for Manufacture and Assembly) strategy, allows for deployment of resources and materials to be carefully pre-planned, making it even easier to monitor and limit over-spend.

EXHIBIT 23: Benefits of lean design for reduced embodied carbon emissions in buildings



[Adapted from source: BrydenWood (2024)[82]]

Passive Design Strategies

Passive design emphasises incorporating design strategies which are passive to solar exposure and utilise the available thermal and visible light spectrum of the sun's energy in the building. Such strategies include optimal building orientation, natural ventilation, and daylighting can significantly reduce energy consumption. These strategies help minimise reliance on mechanical systems, further lowering operational emissions. Passive design strategies majorly focus on operational emissions reduction in the buildings.

The passive design strategies are classified based on the level of the construction (Site level, building level, and component/ equipment level) and their functional groups namely, insulation, ventilation, and shading. The passive cooling strategies can enhance a building's thermal and energy performance when selected optimally in accordance with the local climate conditions. The extent of this impact varies based on the specific strategies employed and the building's design.

Shading

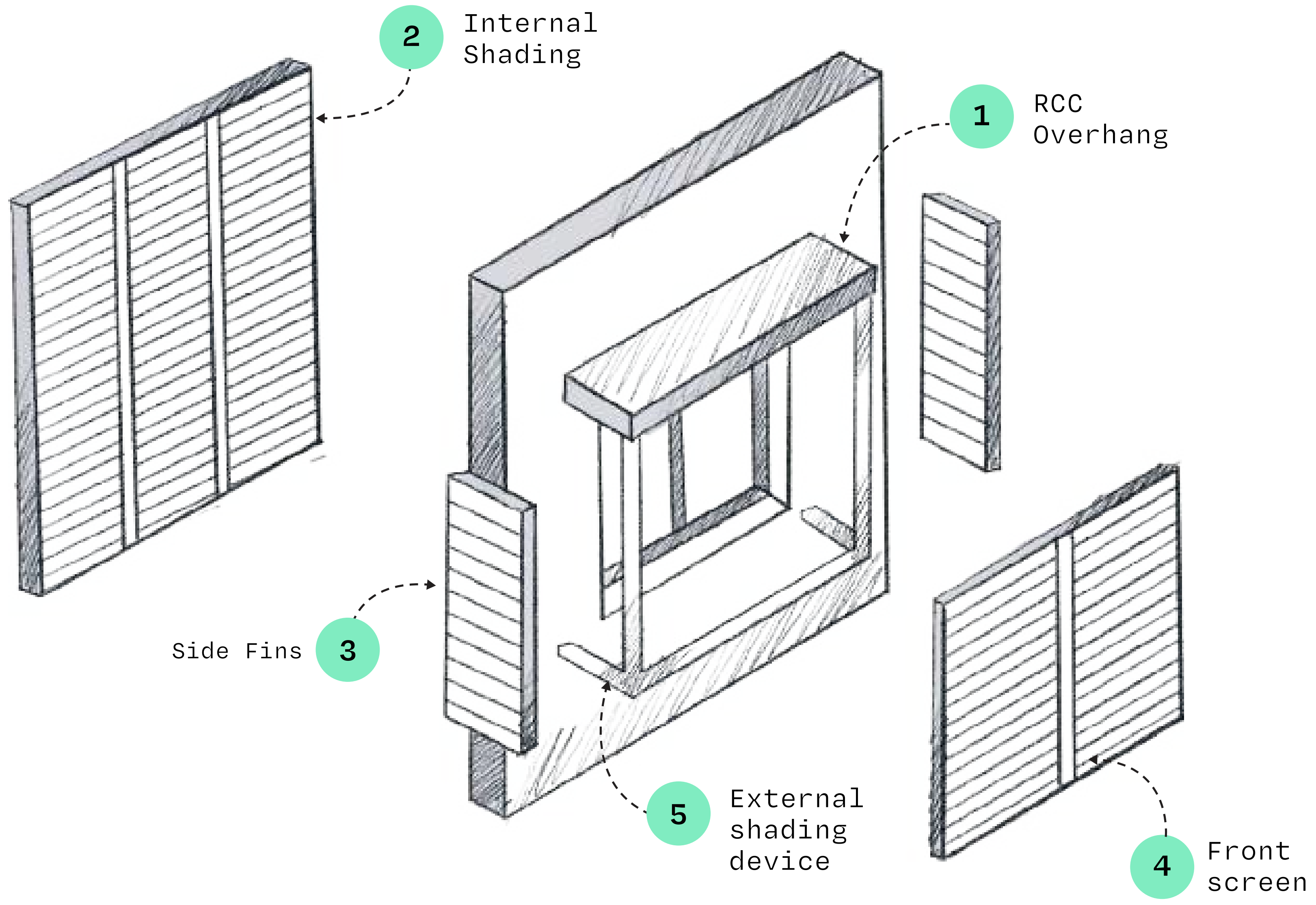
1. External Shading Devices: Overhangs, awnings, and louvres can block direct sunlight from windows, especially on south-facing facades during summer months. This reduces glare and heat gain while allowing sunlight in during winter. Window coverings and coatings can bring up to 60 per cent reduction in unwanted solar heat gain during warmer months. Implementing dynamic shading solutions can result in up to a 30 per cent reduction in cooling energy use.

2. Vegetation: Planting deciduous trees can provide shade in summer while allowing sunlight to penetrate in winter. Green roofs and walls also contribute to shading and insulation.

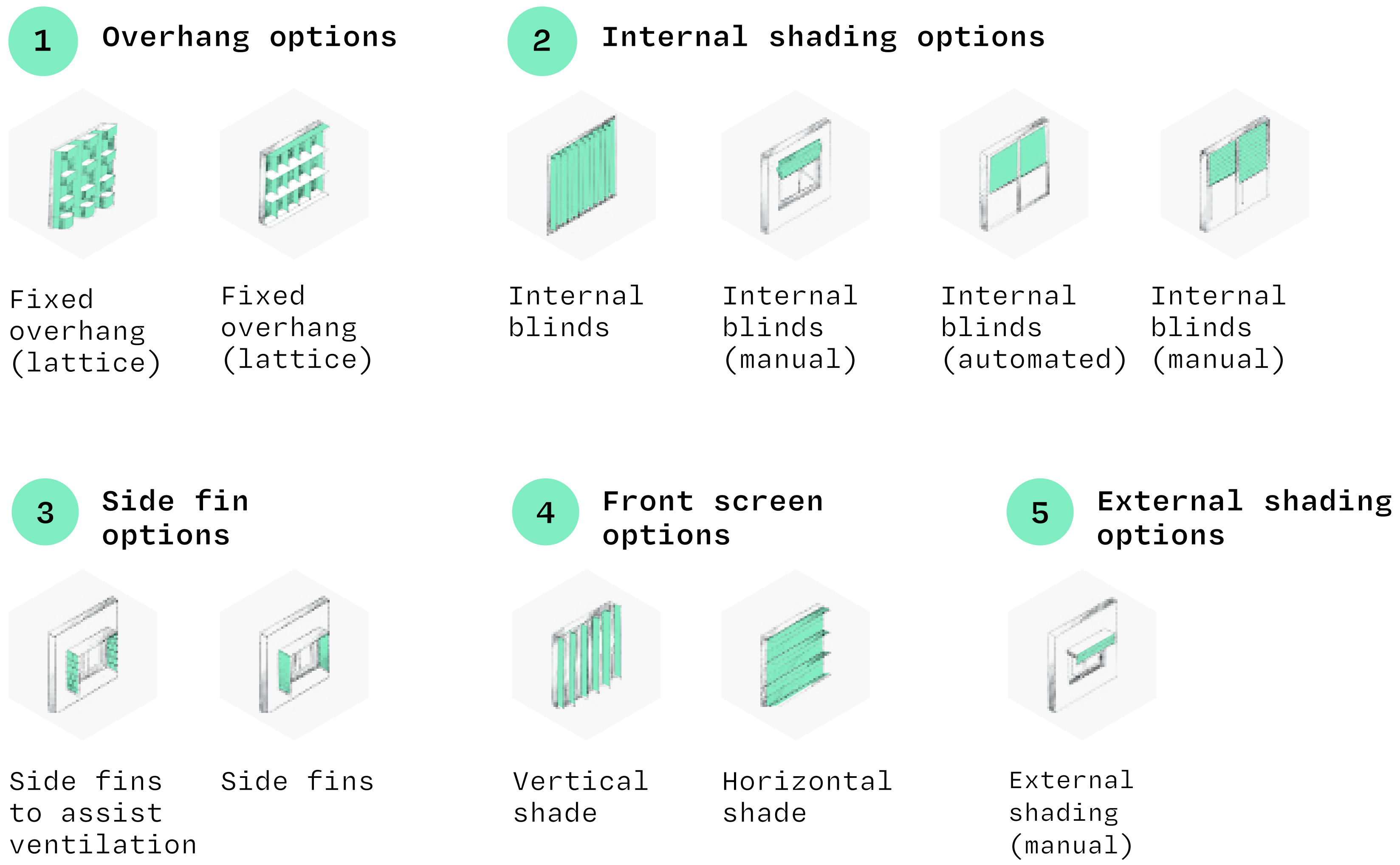
3. Reflective Materials: Using light-coloured or reflective materials for roofs and walls helps minimise heat absorption.

EXHIBIT 24: A selection of different shading strategies

COMPONENTS OF SHADING



SELECTION OF STRATEGIES



[Source: Author's analysis and illustration]

Ventilation

Effective ventilation enhances indoor air quality and comfort by promoting airflow and minimising reliance on mechanical cooling systems, further improving energy efficiency. The key techniques are mentioned as follows.

1. **Natural Ventilation:** This includes cross-ventilation through operable windows and vents that allow cool air to enter while warm air escapes. Stack ventilation utilises the natural buoyancy of warm air to enhance airflow, particularly in multi-story buildings. Combining shading with ventilation can reduce indoor overheating hours by approximately 50 per cent, thereby decreasing the overall energy consumption of the building by about 50 per cent compared to buildings without these measures.
2. **Roof Space Ventilation:** Well-ventilated roof spaces act as a buffer zone, reducing heat transfer into living areas. Ventilators like whirlybirds can enhance this effect by improving airflow across ceiling insulation (1) (2).

Insulation

Insulation is vital for maintaining stable indoor temperatures by minimising heat transfer. Effective strategies include:

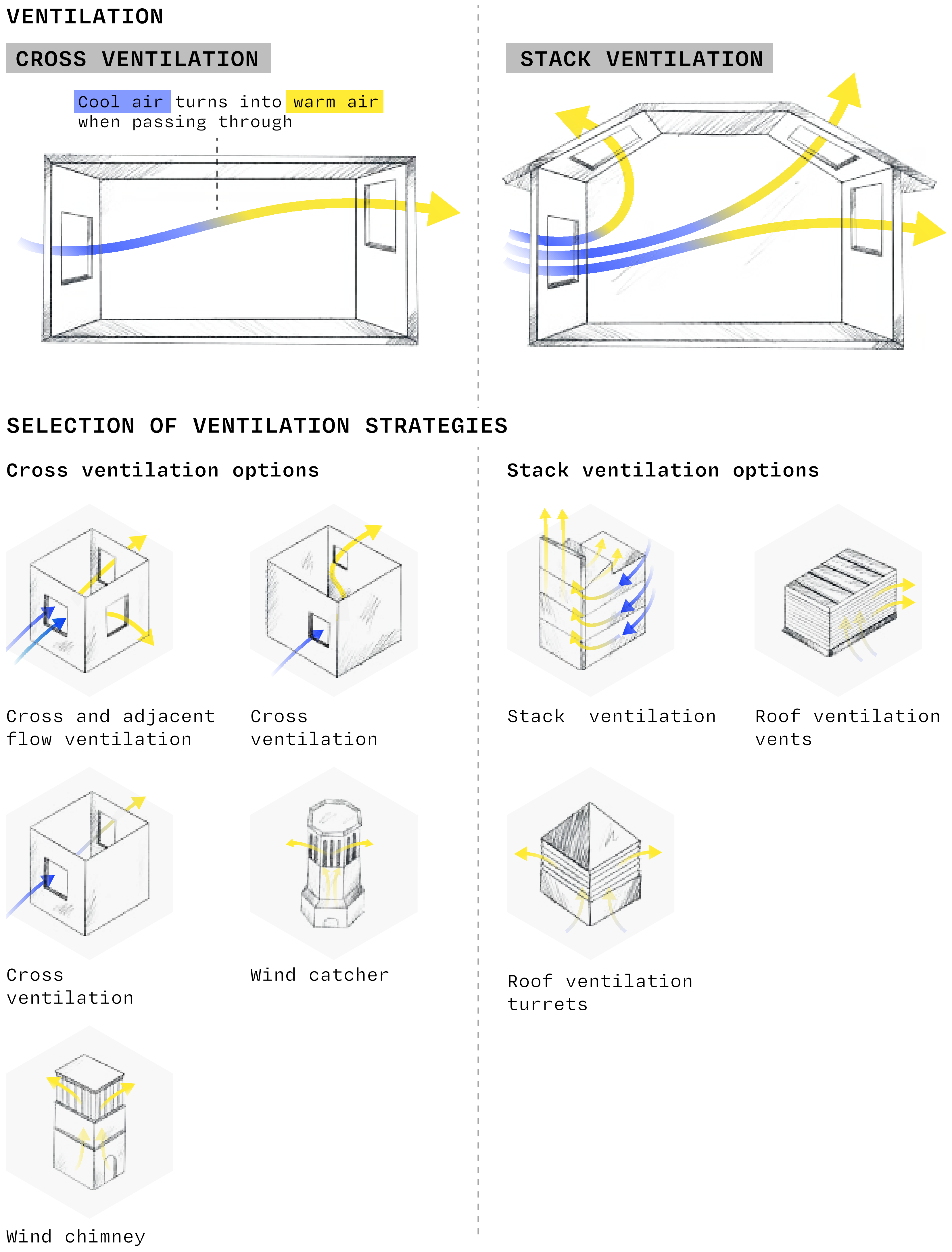
1. **Thermal Insulation Materials:** High-performance insulation materials reduce heat loss through walls, roofs, and floors. This creates a thermal envelope that maintains comfortable interior temperatures year-round . Effective insulation can reduce energy consumption by 15 per cent to 45 per cent, depending on the materials used and the specific areas insulated (walls, ceilings etc.) Insulating roofs alone can lead to a 35 – 45 per cent reduction in energy consumption, significantly contributing to overall building efficiency.
2. **Thermal Mass:** Utilising materials with high thermal mass (like concrete or brick) helps absorb excess heat during the day and release it at night, stabilising indoor temperatures.

Integration of shading, ventilation, and insulation strategies creates a cohesive approach to passive design.

Collectively, passive design strategies can achieve energy savings ranging from 10 per cent to 50 per cent, depending on the specific applications and climatic conditions. Architects can create buildings that are not only energy-efficient but also comfortable for occupants across different climates understanding the integration of these design elements.

Further, incorporating thermal mass, such as concrete or masonry, into the building design helps to regulate indoor temperatures by absorbing and releasing heat. Thermal mass is particularly effective when combined with passive solar heating strategies. Proper shading, both exterior and interior, is essential for controlling solar heat gain and preventing overheating. This can be achieved by using overhangs, awnings, screens, or landscaping elements.

EXHIBIT 25: A selection of different ventilation strategies



[Adapted from source: Author's analysis and illustration]

ES
1
2
3
4
5
6
7
8

CASE 3

Krushi Bhawan, Bhubaneshwar, Odisha

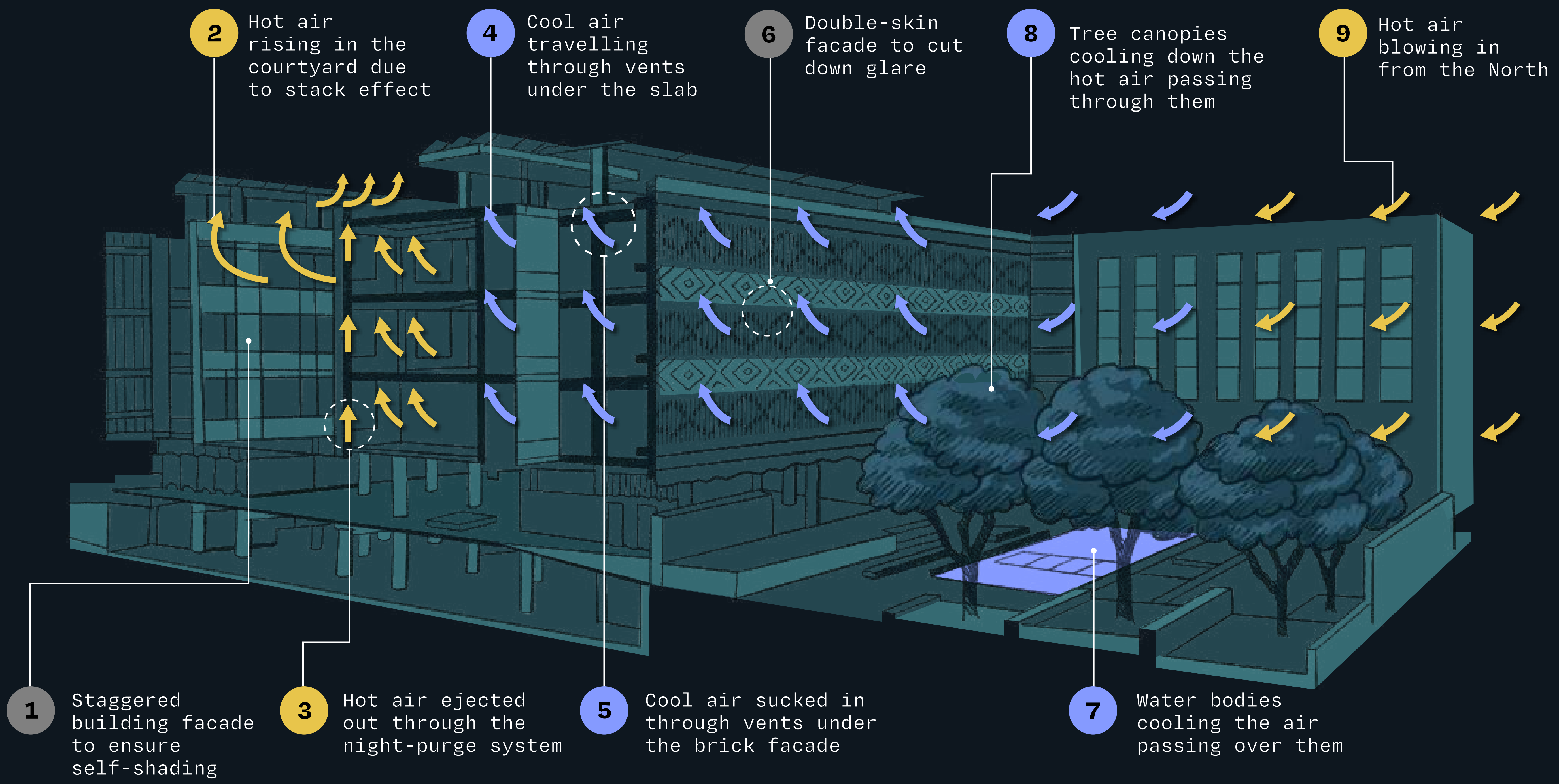
Krushi Bhawan, a government office building located in Bhubaneshwar, Odisha, is a striking office campus, integrating governmental functions with direct community engagement and education. The ground floor of the building is designed as a free-flowing public space, which opens into a plaza, whereas the terrace houses the urban farming exhibits and crop samples to educate the local populace on the best agricultural practices. The restricted-access, purely administrative spaces are placed on the first, second and third floors and consist of workspaces for the State Department and Directorates. Krushi Bhavan received the World Architecture Festival 2019 Highly Commendable Award in the Office Building category.

EXHIBIT 26: An aerial view of Krushi Bhawan captures the striking façade resembling Ikat pattern

[Image credit: Studio Lotus]

The built mass asserts a unique visual identity with a distinctive brick façade inspired by the Ikat patterns of Odisha handlooms, created using clay in three different colours, representing the geographical diversity of the region. The material palette uses a combination of indigenous and locally sourced materials, such as exposed brick and local stones like laterite and Khond alite. The staggered façade provides self-shading for the building. The air from the courtyard gets reduced in temperature because of the landscape and water bodies, which cools the building, and the hot air rises due to stack effect. The night-purging system cools the building and reduces the cooling load. The design scheme includes the courtyard morphology and the inclusion of a stilt level, which aids optimal air circulation through the building. The staggered building profile along the Central Court enables self-shading.

EXHIBIT 27: **Krushi Bhawan is a great example to showcase the integration of several passive design strategies including sourcing of local materials**



[Adapted from source: Studio Lotus]

"The design concept borrows from local vernacular techniques to embed itself into its neighbourhood and the communal values of its people. A major feature is its striking brick facade, inspired by the Ikat patterns of Odisha's handlooms."

- Studio Lotus, Architect

Energy performance of Krushi Bhawan

1. The façade has been designed to ensure 100 per cent daylit internal spaces.
2. The double-skin facade strategy has been put in place at the complex, which consists of double-glazed units (DGUs) on all external fenestration with louvres and sill projections that act as shading devices – a system that reduces heat gain to 40 per cent by regulating ingress of sunlight.
3. A deduction of internal air temperatures by 7-8 °C (in comparison to the ambient temperature) has been achieved through the night-purging system.
4. The use of locally-sourced materials has also lowered the carbon footprint of the construction process.
5. Avoidance of air-conditioning in 80 per cent of the occupied floor area.

CASE 4

Smart Ghar III, Rajkot, Gujarat

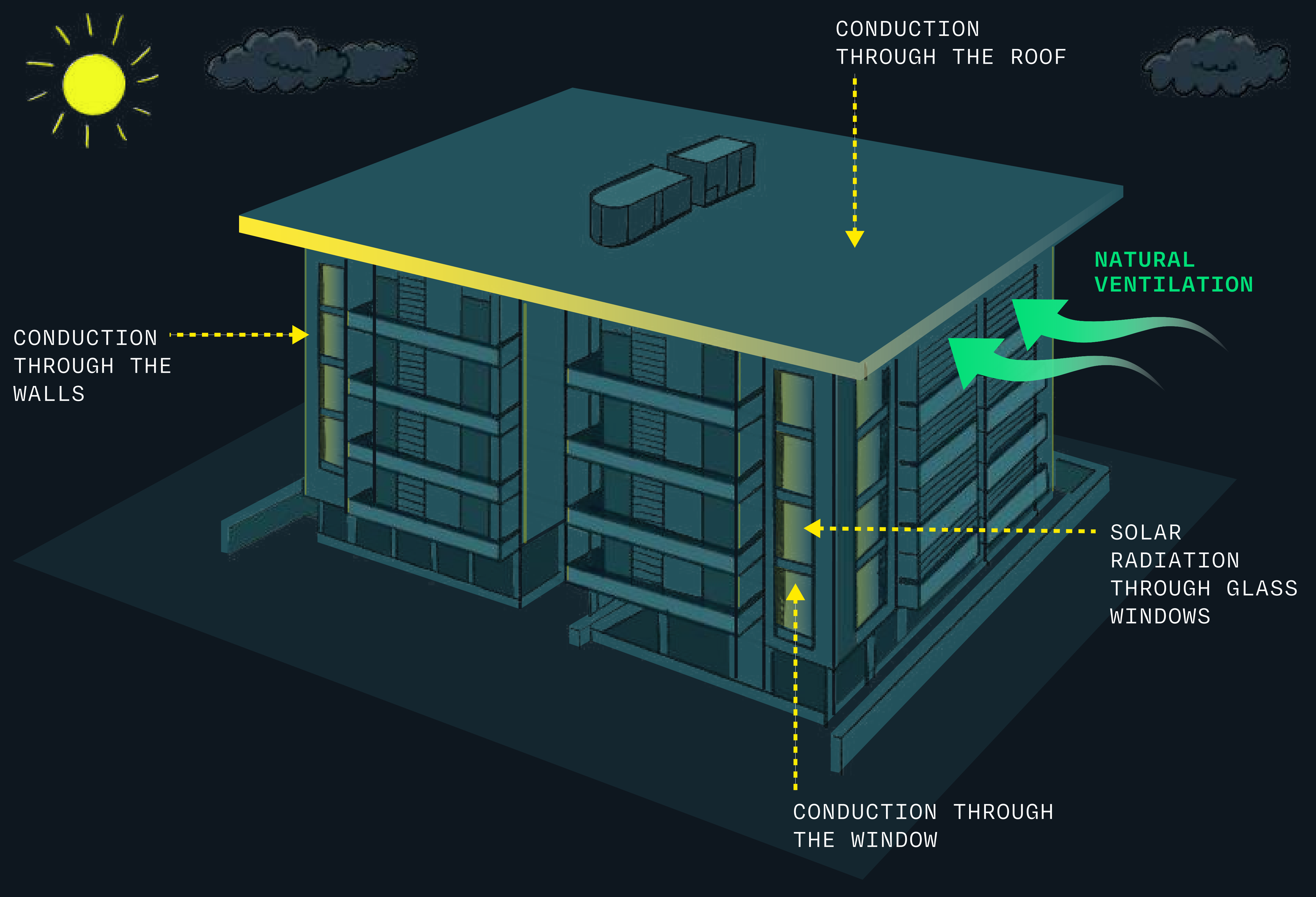
Smart Ghar III is a residential building project located in Rajkot, Gujarat, developed as a passive designed and energy-efficient residential. It is supported by the Rajkot Municipal Corporation and Indo-Swiss Building Energy Efficiency Project (BEEP). This project serves as a model for the Affordable Housing Mission by the State Government to promote thermally comfortable and affordable housing for low-income groups and economically weaker sections of the population.

Passive design strategies in this building include optimised opaque building envelope, use of sustainable materials and natural ventilation. The building showcased in the project improved thermal comfort for the occupants using affordable construction materials, and modulation in the building design.

EXHIBIT 28: Smart Ghar III, Rajkot
[Image credit: Indo-Swiss Building Energy Efficiency Project]

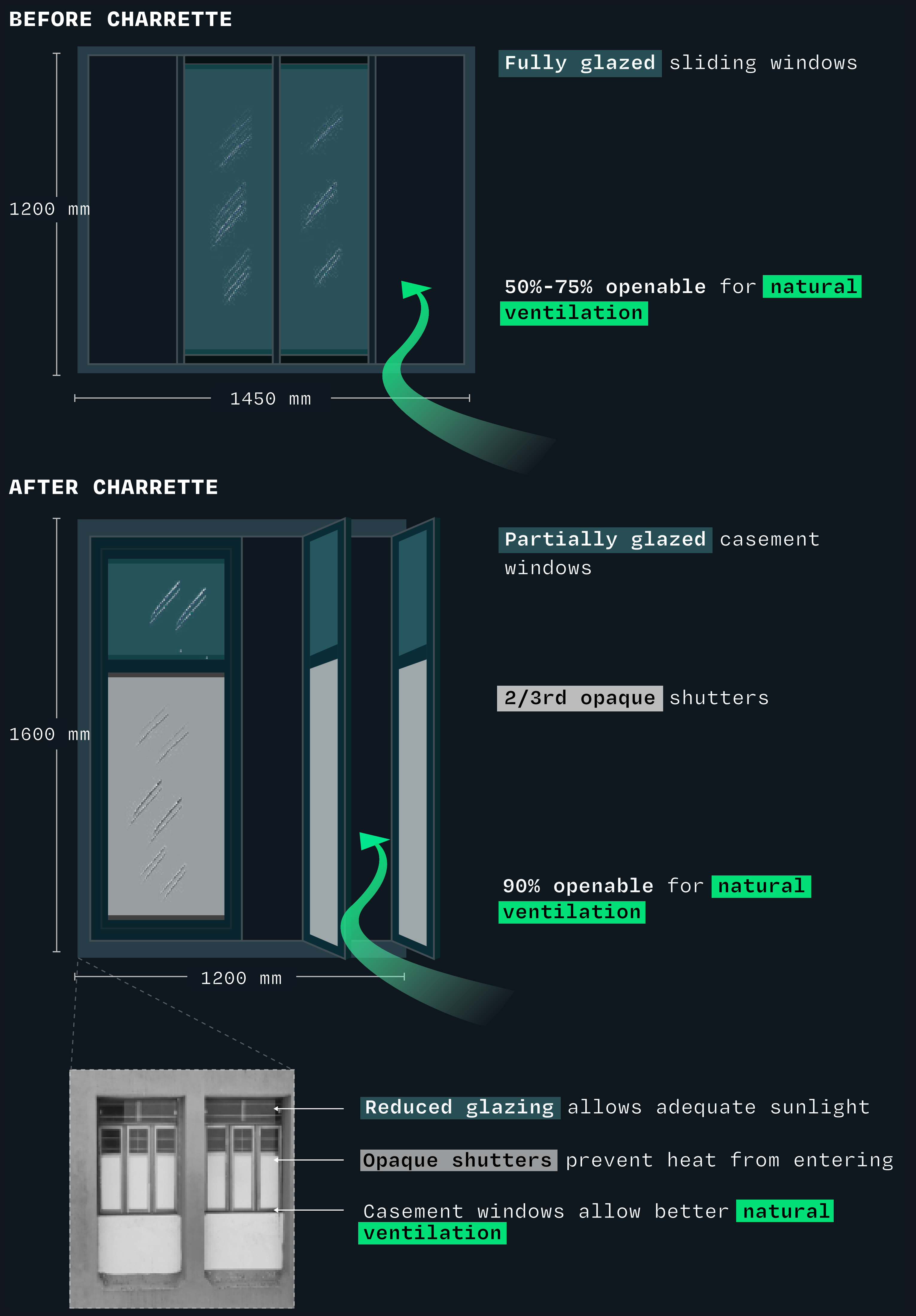
A design charrette training program was conducted with the building construction team (architects, engineers, and construction contractors) to enhance the building design to reduce the window-to-wall ratio, and include an external shading system for the windows, which reduced the heat loads from windows by 30 per cent. This strategy also enhanced the natural ventilation through the windows, during the hours when outdoor air temperatures are lower than the internal air temperature.

EXHIBIT 29: Building Envelope Design - Smart Ghar III



[Adapted from source: Indo-Swiss Building Energy Efficiency Project [83]]

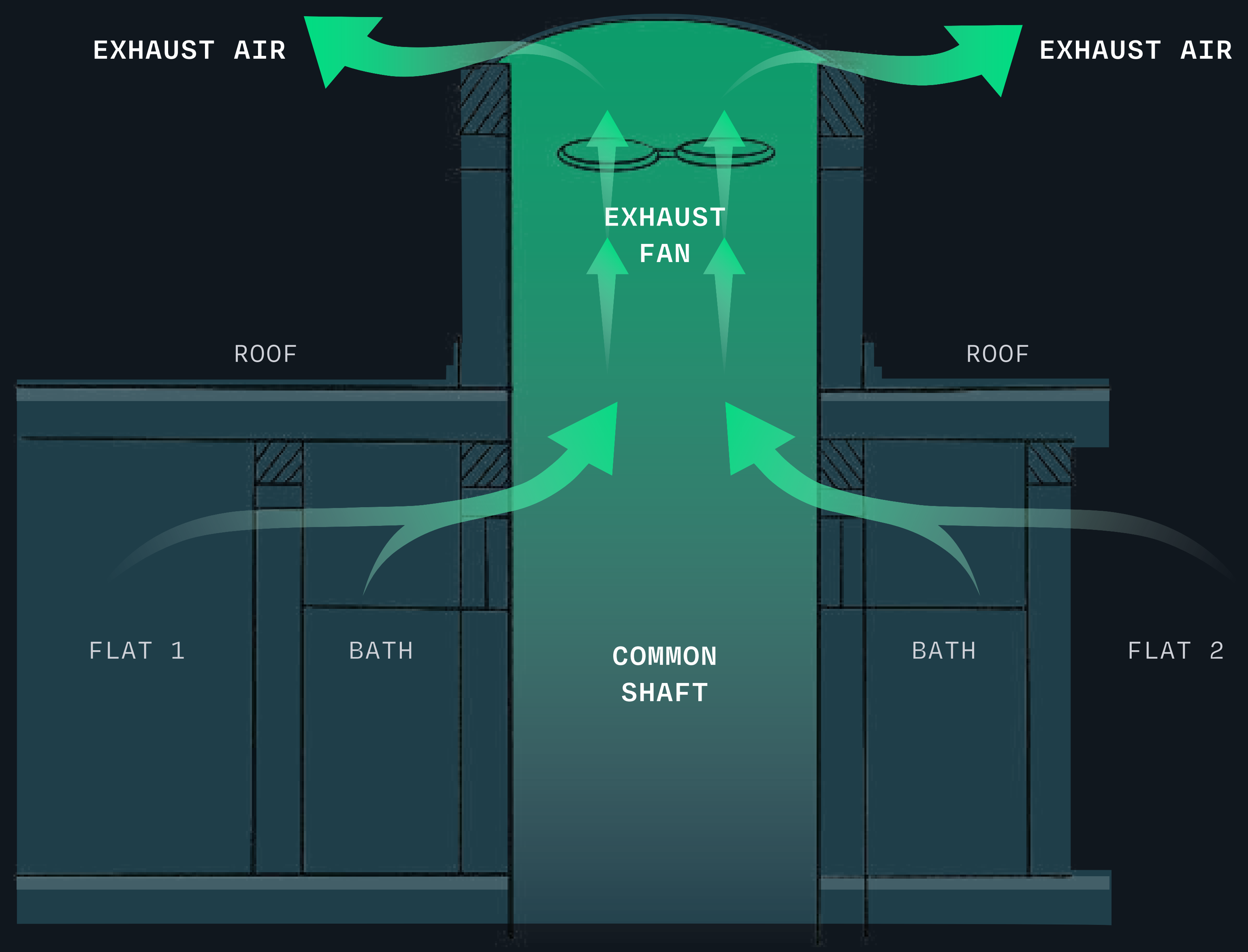
EXHIBIT 30: Upgradation of fenestration design



[Adapted from source: Indo Swiss Building Energy Efficiency Project]

Combined with the passive design measures, the building was integrated with assisted ventilation through a common shaft between flats to enhance the comfort in common areas within the building.

EXHIBIT 31: Assisted ventilation system - Smart Ghar III



[Adapted from source: Indo Swiss Building Energy Efficiency Project]

Post occupancy survey at this development yielded the following results.
Respondents reported that:

35%	**Indoor temperature and air movement to be neutral (neither warm nor comfortable)**
40%	**These variables to be satisfactory during the summer and monsoon months.**
60%	**The relative humidity to be neutral or on the satisfactory spectrum (20 per cent) in the summer and monsoon seasons.**
25%	**Dissatisfaction with the indoor air temperature for the winter months compared with only 10 per cent during the summer.**

KEY LEARNINGS

By adopting these passive design measures, it is estimated to reduce peak summer room temperature by >5°C, as well as increase the number of comfortable hours (those below 30°C) from ~2600 hours to ~6300 hours across the year. The project has showcased how thermal comfort can be enhanced in the households where the cost of construction is low, and affordability for ownership and operation of air conditioners are key concerns for the residents.

CHAPTER 5

Building Scale: Integrating Technology to Tackle Operational Carbon

Residential and commercial buildings in India are responsible for 34 per cent of the total annual electricity consumption.

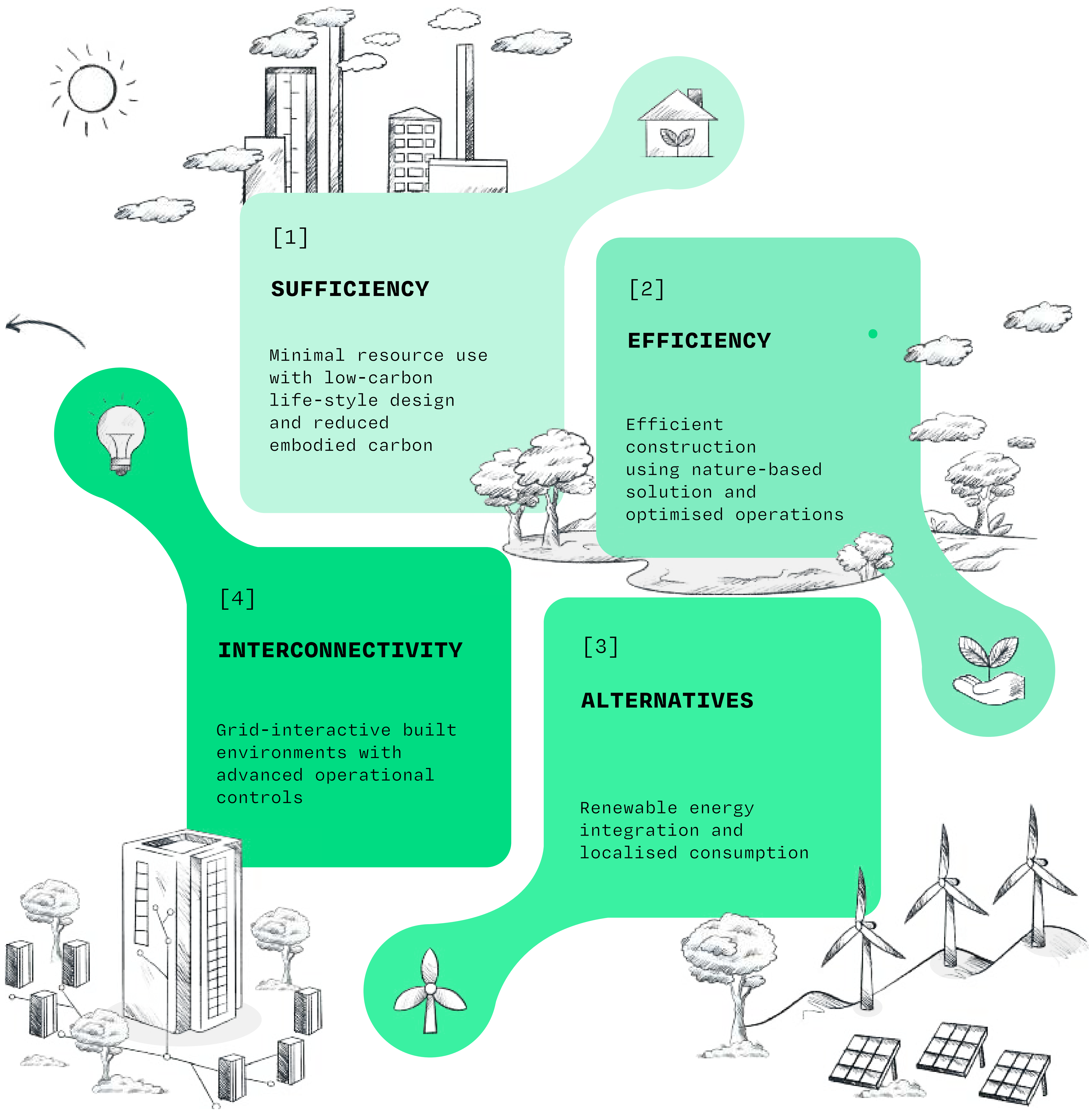
There are substantial environmental and financial benefits of the sustainable design and technologies implemented in the Coral HQ 39 building compared to a typical conventional building.

Further, the total number of residential and commercial building energy consumers has increased by ~40 per cent over the past 8 years, with the sale of electricity increasing by ~46 per cent in the same period.[84] This indirectly indicates the growth in the energy intensity of the buildings sector overall, looking into the fact that the total connected load had increased b y only ~14 per cent over the same period. The same period witnessed a ~65 per cent increase in the revenue from the electricity sales, indicating cost escalation in electricity price of 5.72 INR/kWh to 6.5 INR/kWh. To offset energy use in buildings, developers must turn to integrating technologies such as smart energy management systems, low-energy cooling systems and renewable energy in both greenfield and brownfield projects.

The increasing energy consumption and electricity prices necessitate interventions to improve energy-efficiency and utilise renewable energy to meet the demands from upcoming developments like electrical vehicle charging infrastructure and demand management strategies like Battery Energy Storage Systems (BESS).

The potential integration of on-site renewable energy systems emerges as a strategic avenue to optimise energy usage, thereby reducing reliance on a fossilised grid which leads to reduction in CO_2 emissions. By mitigating losses during energy conversion, this approach minimises the primary energy required to meet existing demands. Furthermore, advancements in energy efficiency not only decrease overall primary energy requirements but also reduce the capacity and cost of low-carbon energy systems necessary for meeting demand.

EXHIBIT 32: Conceptually, emerging buildings technologies for reducing operational carbon emissions can be placed in four focus areas:



[Source: Author's analysis and illustration]

5.1 Sufficiency

Sufficiency in design refers to the practice of designing products, buildings, and systems that fulfil their intended purpose while using minimal resources.

This concept encourages a shift from merely optimising efficiency to considering the broader implications of consumption patterns and resource use.

Dematerialisation: The principle focuses on reducing the amount of material used in products without compromising functionality. By designing lighter and more efficient products, designers can minimise waste and resource extraction.

Modular Design: Creating products that can be easily repaired, upgraded, or reconfigured extends their lifespan and reduces the need for new materials. Modular designs enable users to adapt products to changing needs, promoting longevity.

Product-Service Systems (PSS): Transitioning from selling products to offering services can reduce overall consumption. For example, leasing rather than selling appliances encourages manufacturers to design for durability and repairability, as they retain ownership of the product.

Design for Longevity: Products should be designed to last longer, reducing the frequency of replacement and associated waste. This includes using durable materials and ensuring ease of maintenance.

Local Sourcing: Limiting long-distance transportation by sourcing materials locally reduces carbon emissions associated with logistics. This approach also supports local economies.

User-Centric Design: Understanding user needs and behaviours is crucial for creating sustainable solutions that are not only functional but also desirable. Products that are easy to use and maintain are more likely to be embraced by consumers, leading to reduced waste.

Several technologies have been earmarked to achieve sufficiency.

Technologies identified through pilot Projects in India [85]

1. Precast concrete construction system – 3D precast volumetric
2. Precast concrete construction system –precast components assembled at site
3. Light gauge steel structural system & pre-engineered steel structural system
4. Prefabricated sandwich panel system
5. Stay in place formwork system

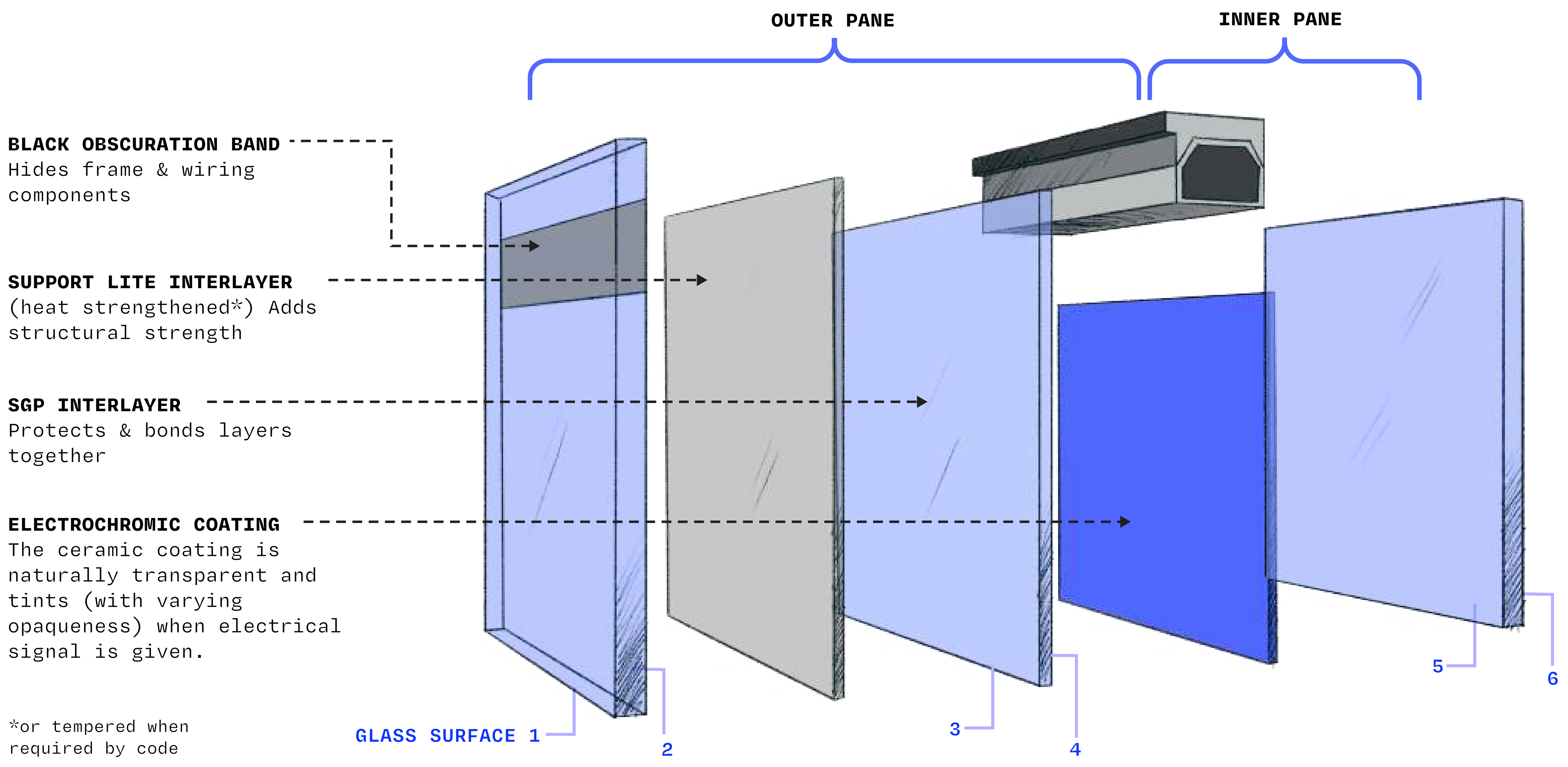
5.2 Efficiency

The efficient systems and appliances help in reducing operational energy consumption in buildings.

A large variety of solutions are available in this category that can help achieve this at on par lifecycle cost. Some of the most promising technologies include:

1. **High Performance Electrochromic Smart Glass**
   This involves windows that can change their tint electronically to control heat and light entering a building. By maximising natural light while minimising heat gain, electrochromic glass contributes to reduced energy consumption for heating and cooling.

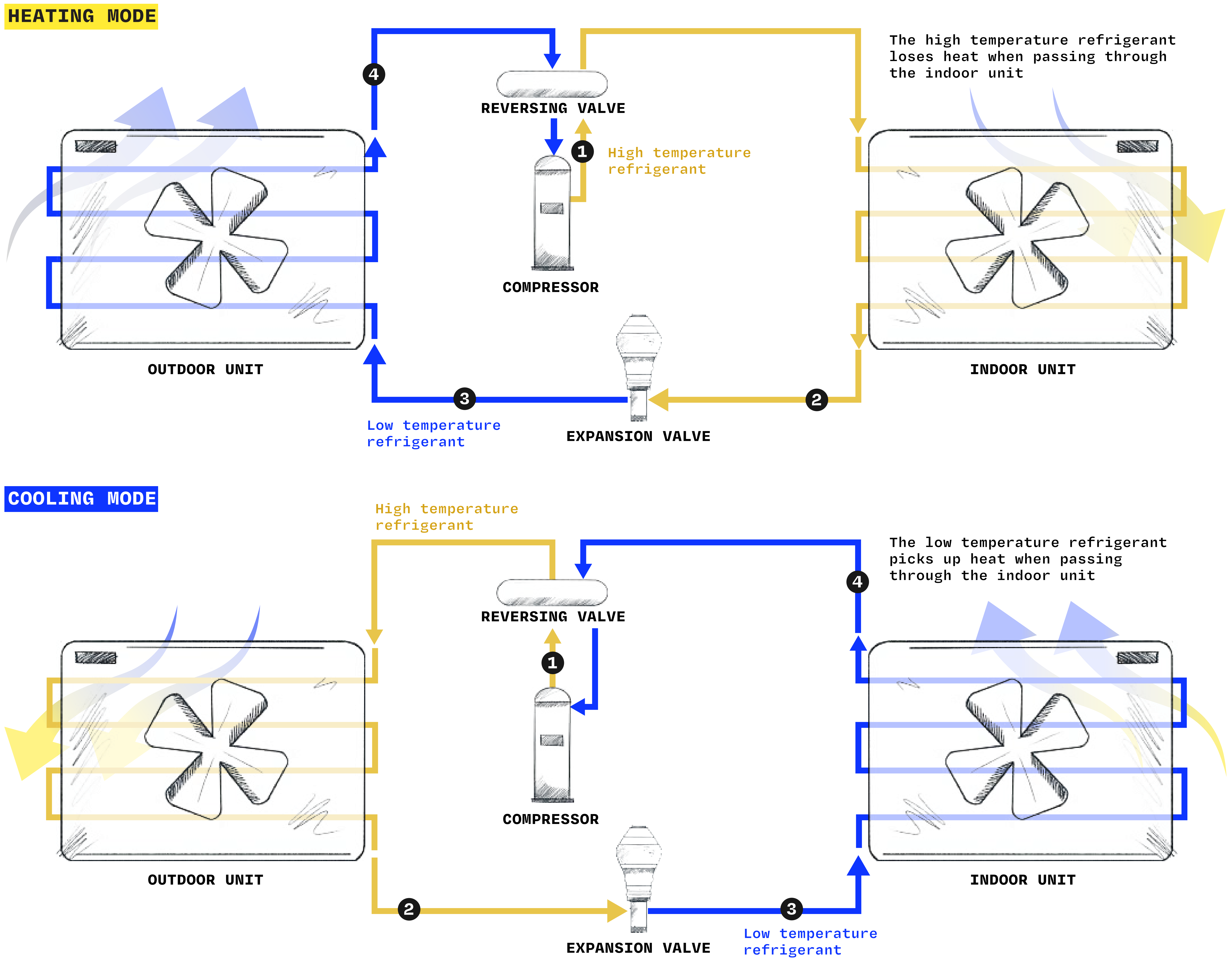
EXHIBIT 33: Illustration of Electrochromic Smart Glass



[Adapted from source: SageGlass, Saint-Gobain[86]]

ES
1
2
3
4
5
6
7
8

EXHIBIT 34: A schematic of how heat pumps work in cooling and heating modes



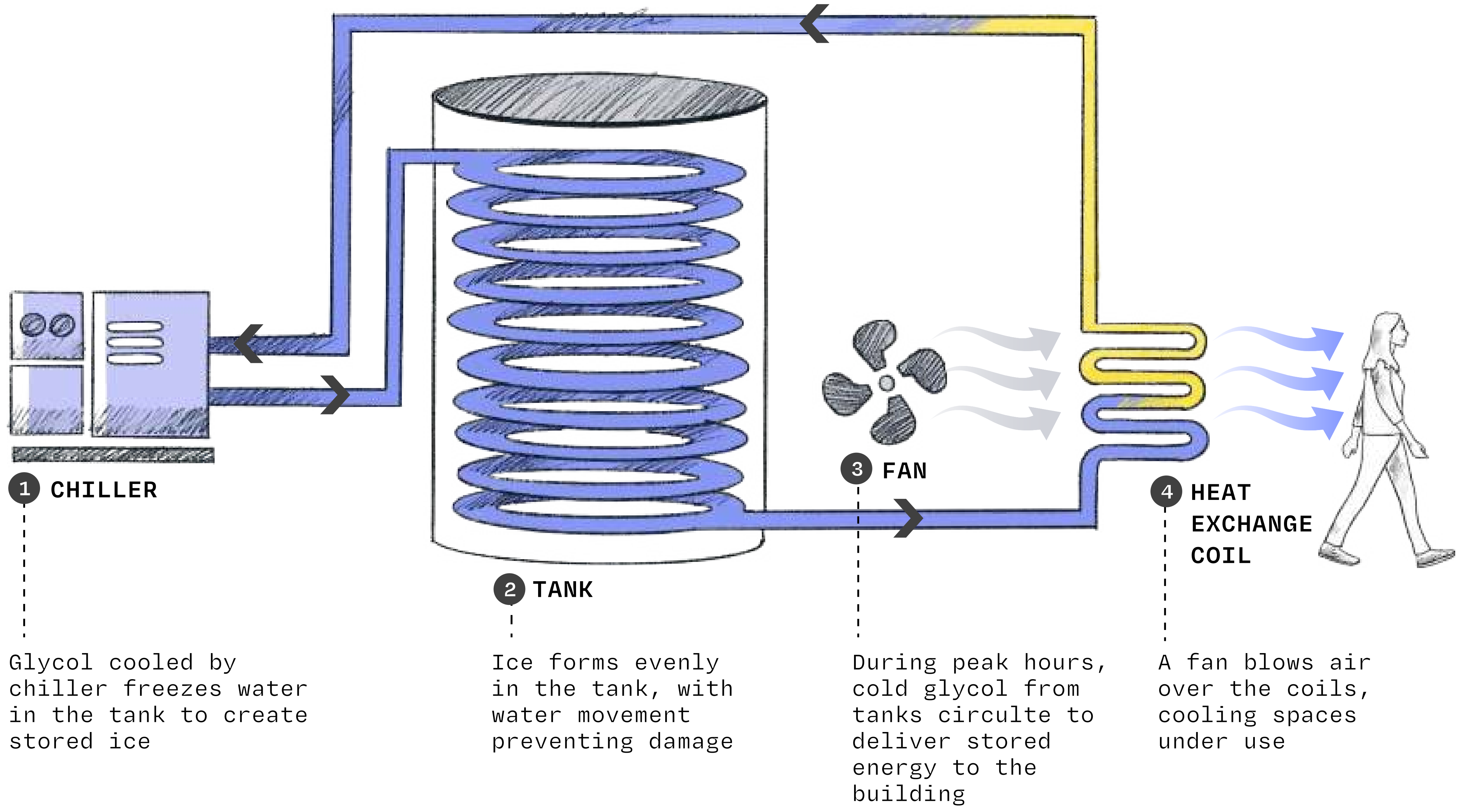
[Adapted from source: The Engineering Mindset, Trane Technologies[87]]

When in cooling mode, a heat pump functions similarly to an air conditioning system but at a higher efficiency.

2. **Heat Pump Technologies**

Heat pumps are effective for providing both cooling and heating, utilising ambient heat from the media like ambient air, ground, or water, at a higher efficiency than a conventional room air-conditioner. Their deployment can lead to substantial energy savings and reductions in greenhouse gas emissions, especially when integrated into buildings in composite and temperate climates in India.

EXHIBIT 35: A schematic of the working of thermal energy storage systems



[Adapted from source: Calmac[88]]

3. **Thermal Energy Storage**
   This technology allows buildings to store excess thermal energy for later use, helping to balance energy demand and supply. It is particularly beneficial when paired with renewable energy systems, enabling more efficient energy use. The excess solar power available during the day can be used to cool water and store it for use during the night. On the other hand, nighttime temperatures can enable efficient cooling, which can also enable storage of chilled water for use the following day.

4. **Smart Building Systems**
   The integration of Internet of Things (IoT) devices and AI enables real-time monitoring and optimisation of energy consumption. These systems can adjust lighting, cooling, and other household appliances, based on occupancy and environmental conditions, leading to significant energy savings.

5. **Grid Interactive Built Environment**
   The integration of smart grid technologies can help improve the reliable energy access and enhance the management of energy distribution, allowing buildings to optimise their energy use based on real-time data about supply and demand. This helps integrate renewable energy sources more effectively into the building's operations.

EXHIBIT 36: **Coral 39 HQ represents a vision for future high-performance buildings achieved by leveraging technology integration with passive design strategies**

[Image credit: Coral Life[89]]

CASE 5

Coral HQ 39, Bangkok

The Coral Headquarters in Bangkok has achieved an impressive 70 per cent reduction in energy demand as compared to conventional buildings in the warm and humid climate of Bangkok. This energy-efficient building incorporates a range of advanced technologies, passive design strategies, and active systems to minimise its environmental footprint while maintaining superior indoor comfort. The passive design strategies in the building include higher insulation in wall and roof, improved airtightness and avoiding thermal bridging across the structure. Low-Emissive Double-Glazed Windows are installed to reduce heat gain while still allowing natural light to penetrate.

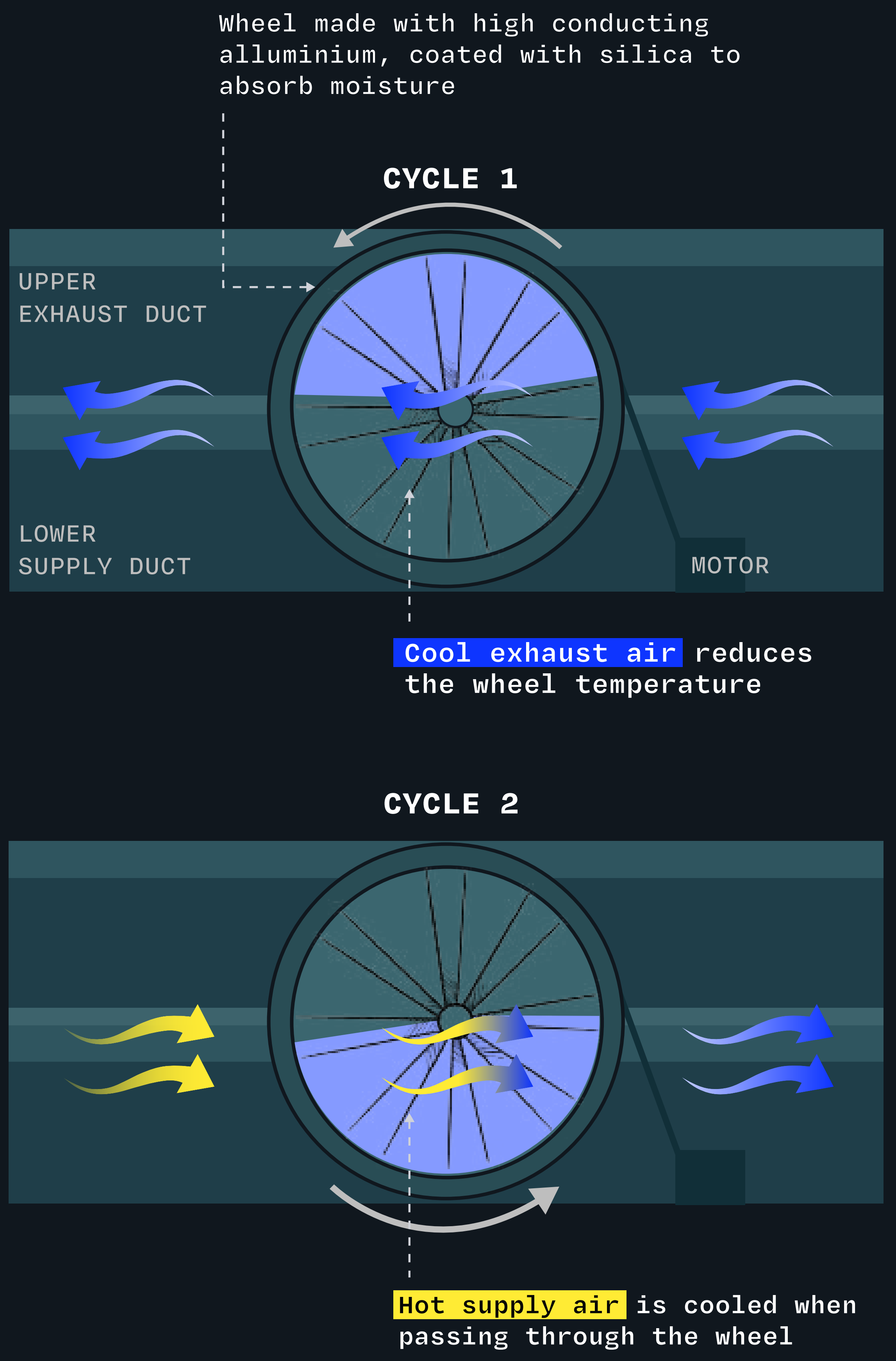
Technologies Used to Enhance Energy Efficiency

1. **Heat Recovery Wheel System**
The Coral HQ 39 building uses a heat recovery wheel system that captures the cooling energy from the exhaust air to pre-cool incoming fresh air. This significantly reduces the cooling load and enhances the building's overall energy efficiency.

2. **IoT-Enabled Indoor Air Quality and Free Cooling:** The building integrates smart IoT technology to monitor indoor air quality and temperature in real time. When outdoor temperatures drop below a certain threshold, the system automatically switches to use the free cooling effect from outside air, reducing the need for mechanical cooling.

3. **Solar Photovoltaic (PV) System**
Solar PV Energy Generation: The building incorporates solar cells to generate 30 per cent of its energy needs on-site, making Coral HQ 39 a net-zero energy building. The integration of solar power drastically reduces dependence on grid electricity and further enhances the building's sustainability.

EXHIBIT 37: Workings of a heat recovery wheel system



[Source: Coral Life]

EXHIBIT 38: Energy performance of Coral HQ 39

[Source: Coral Life]

INDIA IN FOCUS - KEY LEARNINGS

The Coral 39 HQ has set a precedent for better quality of life for its users using an effective thermal comfort system and IOT technologies, supplemented by renewable energy supply in the warm and humid climate, a climate prevalent across Indian coastal regions. Maintaining sufficient indoor environmental quality is a challenge for both developers and users. The combined use of energy efficient mechanical ventilation technologies and integrated IOT based controls can improve the health and well-being of occupants. Adoption of these technologies by end users requires a push from the policy environment for buildings in India, especially the implementation and enforcement mechanisms to ensure energy code compliant/ green rated buildings achieve their stated performance in the design stage.

5.3 Alternatives

The combination of sufficiency and efficiency measures can maximise the reduction in carbon emissions and consumption intensity, but the transition towards carbon-free operations can only be achieved with the support of alternative or renewable energy sources.

Several forecasts envision a global surge in electricity's share in final energy consumption

Present energy consumption	~20%
Surge in energy consumption by 2050	~50%
Anticipated energy generation from solar and wind	~60%

The transformative shift towards low-carbon operations supports a higher proportion of renewable sources in the energy mix, cultivating a more sustainable and cost-effective energy landscape. Several forecasts envision a global surge in electricity's share in final energy consumption from the present 20 per cent to nearly 50 per cent by 2050.[90] This paradigm shift anticipates over 60 per cent of electricity generation originating from solar and wind. Concurrently, adaptive measures such as adjustments in EV charging, electrified heat, and hydrogen production are expected to accommodate variable renewable energy, contributing to the need of establishing a flexible and resilient energy system.

Some of the key technology cohorts in this focus area are as follows:

1. **Renewable Energy Integration:** The technologies in use like solar photovoltaic and thermal power generation systems, wind turbines, and micro-hydro systems are advancing into better maturity stages, whereas technologies like geothermal power generation and thermal energy systems are expected to create a breakthrough to generate clean energy/ reduce consumption on-site.
2. **Waste Valorisation:** Technologies that convert waste materials into usable building products contribute to a circular economy in construction by reducing waste and lowering the carbon footprint associated with material production.
3. **Green Hydrogen:** Emerging as a clean fuel alternative, green hydrogen can be produced using renewable energy sources and has potential applications in heating systems within buildings, contributing to lower operational emissions.

ES
1
2
3
4
5
6
7
8

CASE 6

Gainwell CAT Private Limited, Noida, Uttar Pradesh

Gainwell CAT office building, located in Greater Noida (composite climate), is a 3-storey building with an area of 4,945 m^2, and part of the 5-acre Industrial campus, completed in 2018. The building incorporates integrated design approach, climate responsive high-performance building design, low energy cooling system and integrated renewable energy system.

The passive design concepts in the building include controlled daylight in office and industrial workspaces through incorporation of skylights and roof monitors. Shading Devices are integrated to further manage daylight and solar heat gain in the building. Light shelves are integrated to distribute glare-free daylight into the depths of the habitable spaces. Insulated walls and roof provide a better thermal performance in the building envelope. A roof garden has been incorporated into the design to mitigate the impact of direct solar radiation on the building's roof, one of the largest surfaces exposed to sunlight.

The technologies integrated in the building include Low Energy Radiant Cooling System, combined with Interconnection of Passive and Active Free Cooling Systems using IOT technologies, and a Solar Photovoltaic system to supplement building energy needs.

EXHIBIT 39: High efficiency technologies are seamlessly integrated with passive design measures to achieve net zero status for Gainwell CAT

[Image credit: Net Zero Energy Buildings Project]

Radiant cooling system

The well-designed envelope is complimented by the low-energy consuming radiant cooling system with higher fresh air supply for meeting the latent loads in the building, providing a 37 per cent reduction in the cooling demand, compared with a VRV system. The system provides cooling over the periods of April to September, whereas radiant heating is provided in the months of December and January. Rest of the months are covered with passive free cooling, enabled by the ventilation system.

EXHIBIT 40: A combination of radiant and passive cooling help reduce energy consumption used for cooling

MONTHLY VENTILATION SYSTEM USAGE IN THE GAINWELL CAT BUILDING

RADIANT HEATING SYSTEM

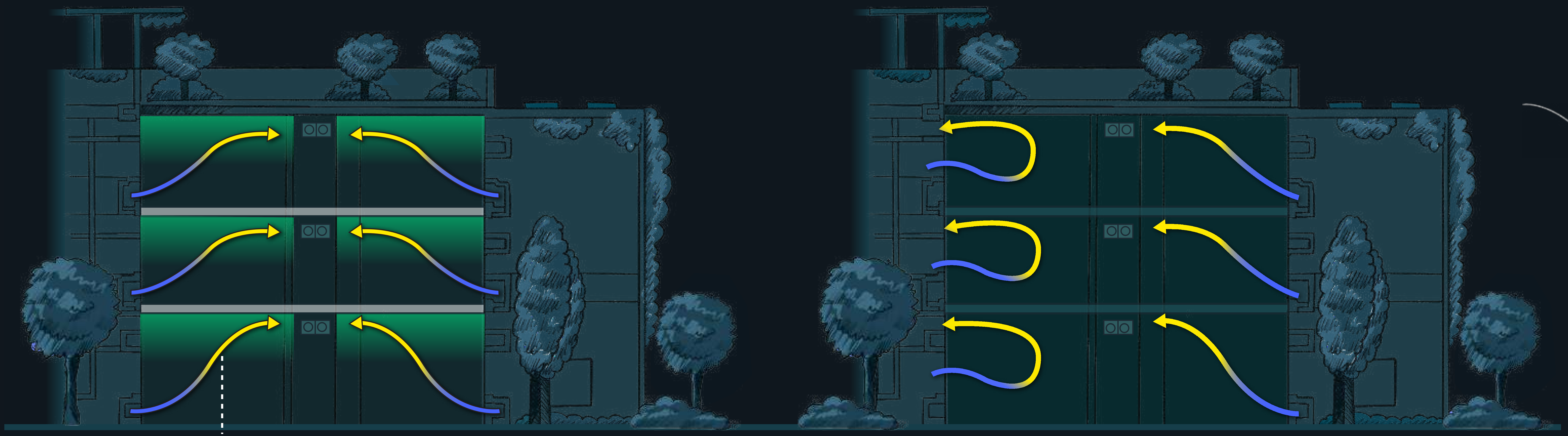
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

RADIANT COOLING SYSTEM

Radiant cooling systems use temperature-controlled water or electric elements embedded in floors, walls, or ceilings to transfer thermal energy directly to or from a space

NATURAL AND MECHANICAL SYSTEM

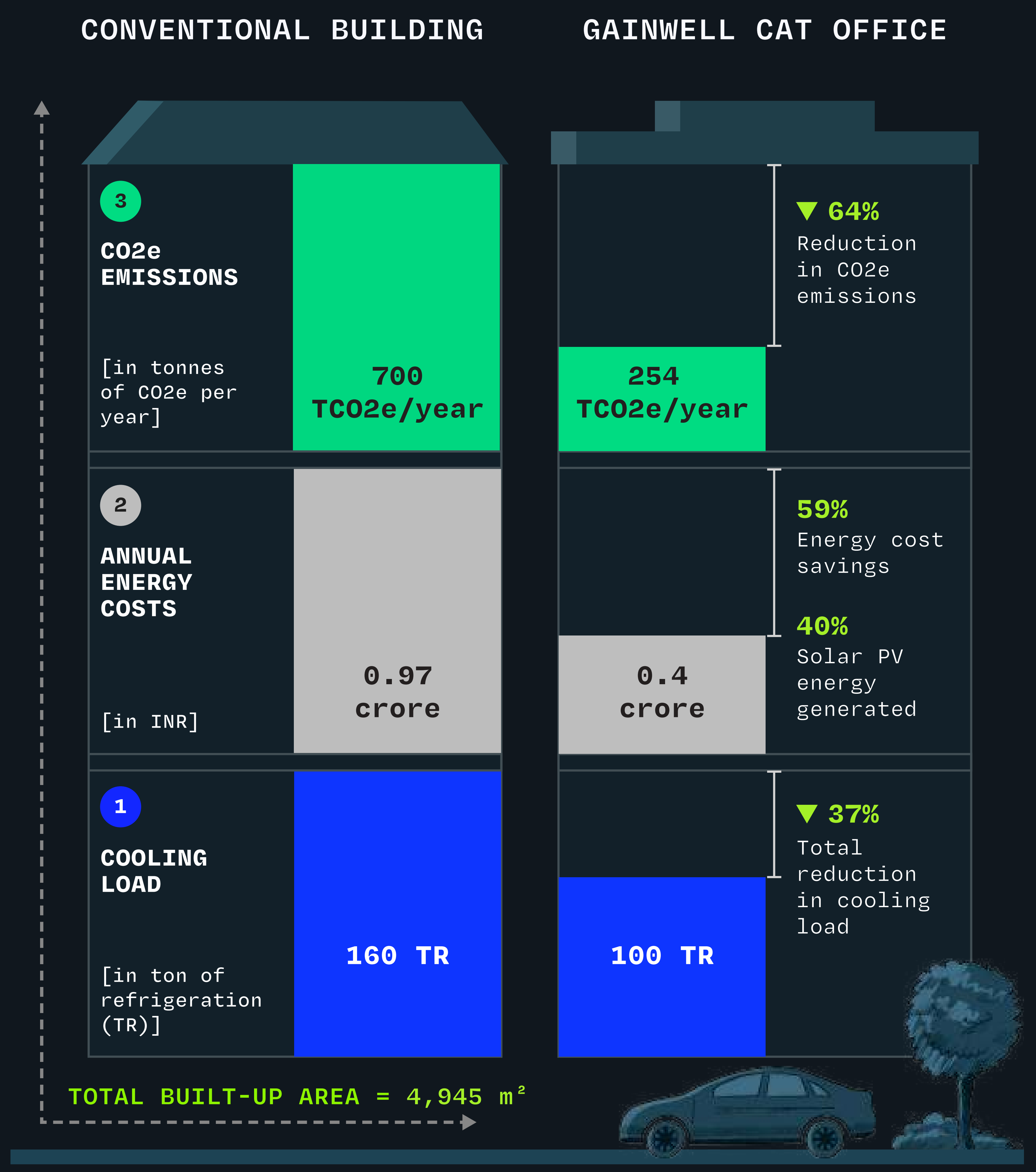
Natural ventilation passively uses wind and thermal differences to move air, while mechanical ventilation actively circulates air using powered fans and ductwork.



The Gainwell CAT building takes a hybrid approach to cooling, heating and ventilation based on the time of the year.

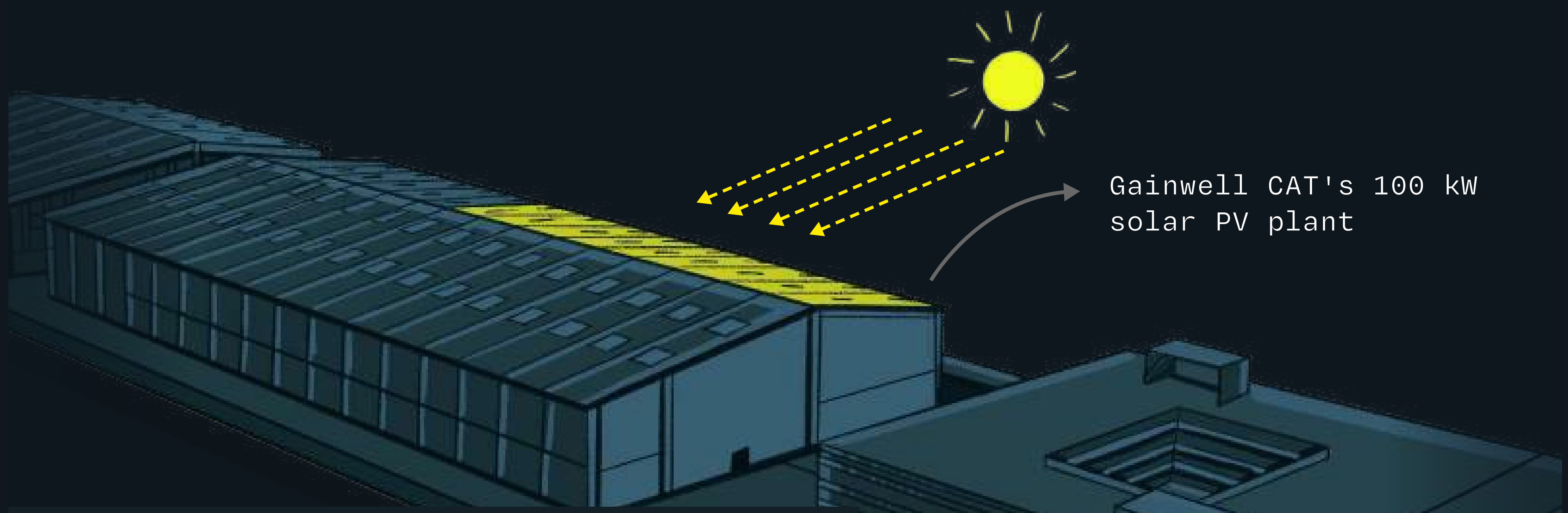
[Source: Net Zero Energy Building Project]

EXHIBIT 41: Energy performance of Gainwell CAT office building



[Source: Net Zero Energy Buildings Project]

EXHIBIT 42: The building is integrated with a 100-kW solar PV plant, which caters to 40 per cent of the energy needs in the building.



PARAMETER	VALUE
Size of the solar plant	100 kW
First year power generation	150,000 kWh
Annual degradation in solar modules	0.5%
Total power generated over life of solar plant	3,533,393 kWh
Life of the solar plant	25 years

Figures, as given by NOHARA Solargy

[Adapted from source: NOHARA Solargy]

KEY LEARNINGS

Adopting not-in-kind low-energy cooling systems like radiant cooling systems and integrating the combination of passive free cooling with mechanical ventilation systems can result in higher reduction of energy consumption. Integrating high-efficiency and low environmental impact technologies like geothermal cooling system, thermal energy storage, vapour absorption Systems, and Indirect-Direct Evaporative Cooling system can reduce the cooling energy use to a maximum extent. Conducting integrated design charrettes in the conceptual design stage with all project stakeholders can help ideate, analyse, and select the suitable measures for specific projects.

5.4 Retrofit solutions

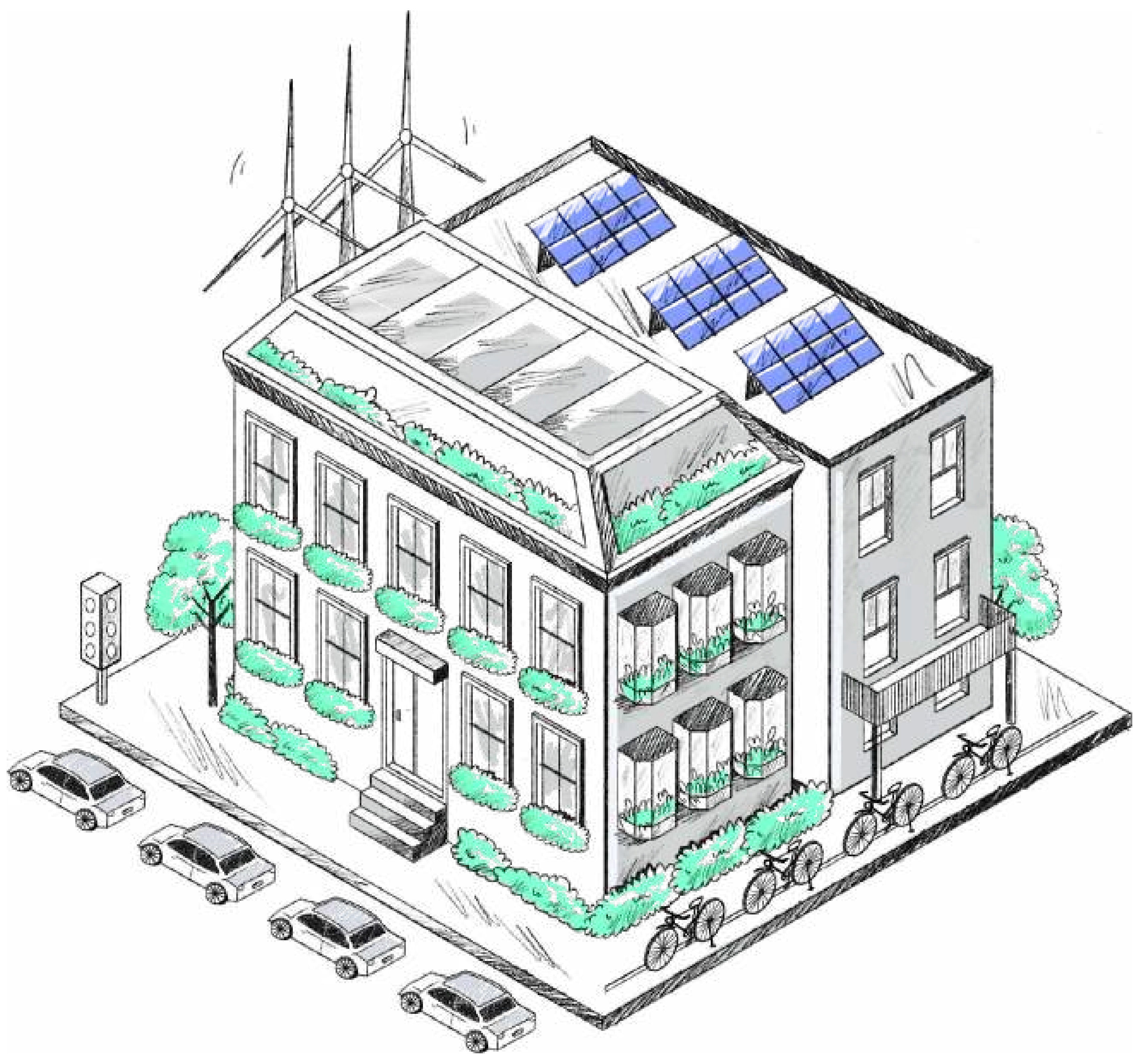
Retrofit solutions for heritage and in-use buildings present another space for intervention.

An empirical study based on the data collected from 235 certified green homes in the US found:

▼ **Retrofit projects on average cost less than new projects** ~49%

A bespoke approach is usually taken to undertake retrofitting of buildings to reduce the operational carbon. It is generally achieved through high performance window installations, advanced insulation, highly energy-efficient systems, integration of renewable energy, greening etc.

Some types of sustainability retrofits will cost more than others, and the nature of the retrofits will affect their cost as well depending on what materials are used and what work is required. However, retrofits can substantially save costs if they significantly reduce energy or water usage over time. An empirical study based on the data collected from 235 certified green homes in the US found that retrofit projects on average cost about 49 per cent less than new projects.[91] In India, retrofit solutions space is still small, mainly due to the large stock of new buildings coming up. Mainstreaming these solutions can unlock a substantial opportunity.



CASE 7

UN House, Lodhi Estate, Delhi

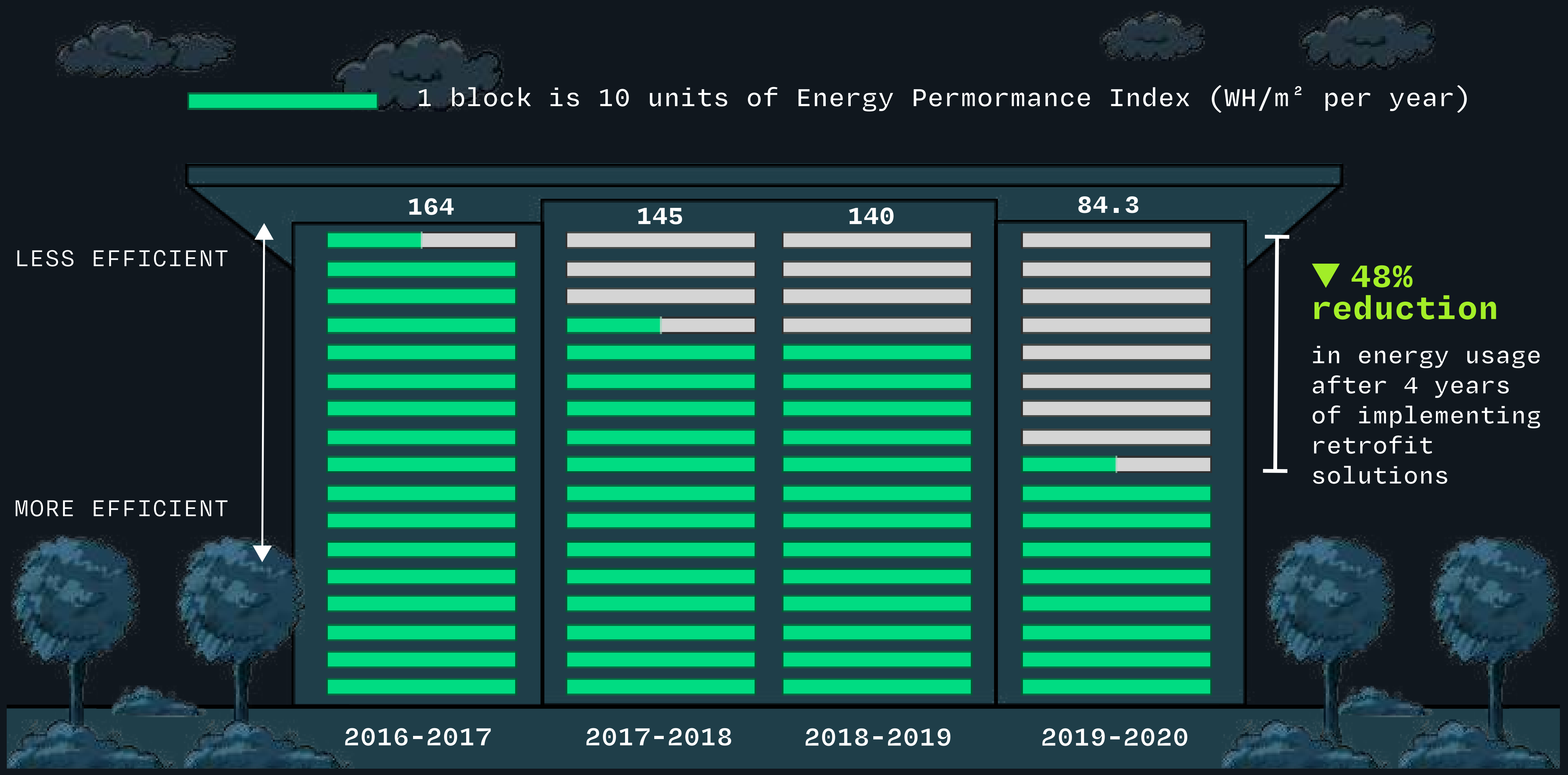
The UN House building along with the Ford Foundation building is at 55, Lodhi Estate, Delhi. The building was designed by the renowned Architect Joseph Allen Stein and has been operational since 1974. Over the years, the building has seen modifications in its interior layout and updates to office appliances and facility management practices. The UN House building site has a total area of 6,426 m^2, including the Ford Foundation building. The UN House India is managed by UNDP for its facility operation, where 15 different UN entities are hosted in the building located in New Delhi. The building has undergone a major energy-efficiency retrofit and renewable energy integration through which the energy performance and the greenhouse gas emissions associated with energy use have been reduced.

EXHIBIT 43: The facade view of the UN house building

[Image credit: Integrative Design Solutions Private Limited]

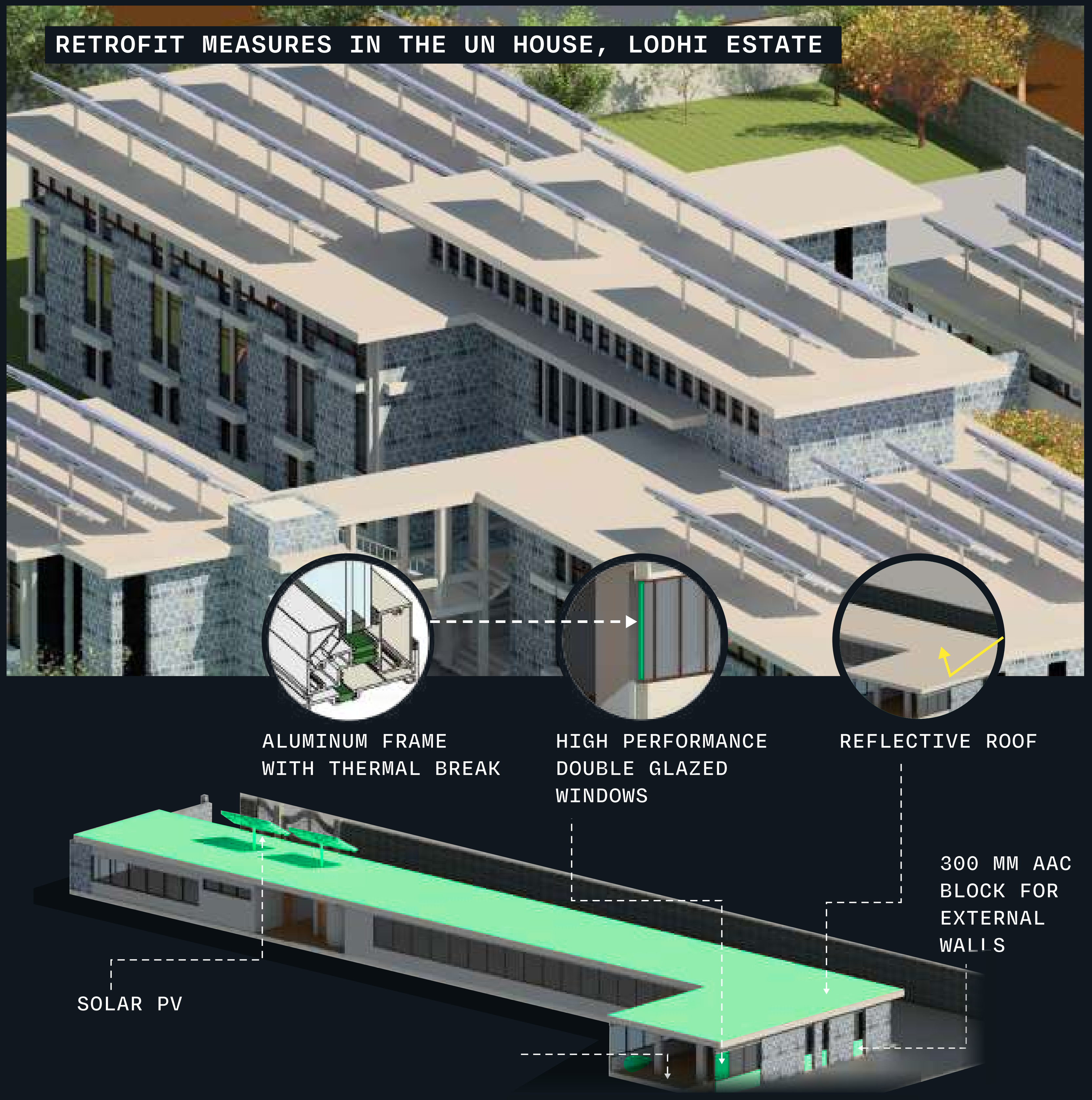
The building also integrated a 172 kWh Solar PV plant in its rooftop, offsetting 31 per cent of annual energy use with clean energy generation. In March 2023, the building received the LEED green building certification for facility operations and management under O+M: Interiors category with Platinum level (Sustainability Score of 87/100). The building has received the National Energy Conservation Award India – 2020 under the Office Buildings Category and GRIHA 4-Star Rating.

EXHIBIT 44: The retrofit solutions have helped achieve reduction in energy use by about 48 per cent



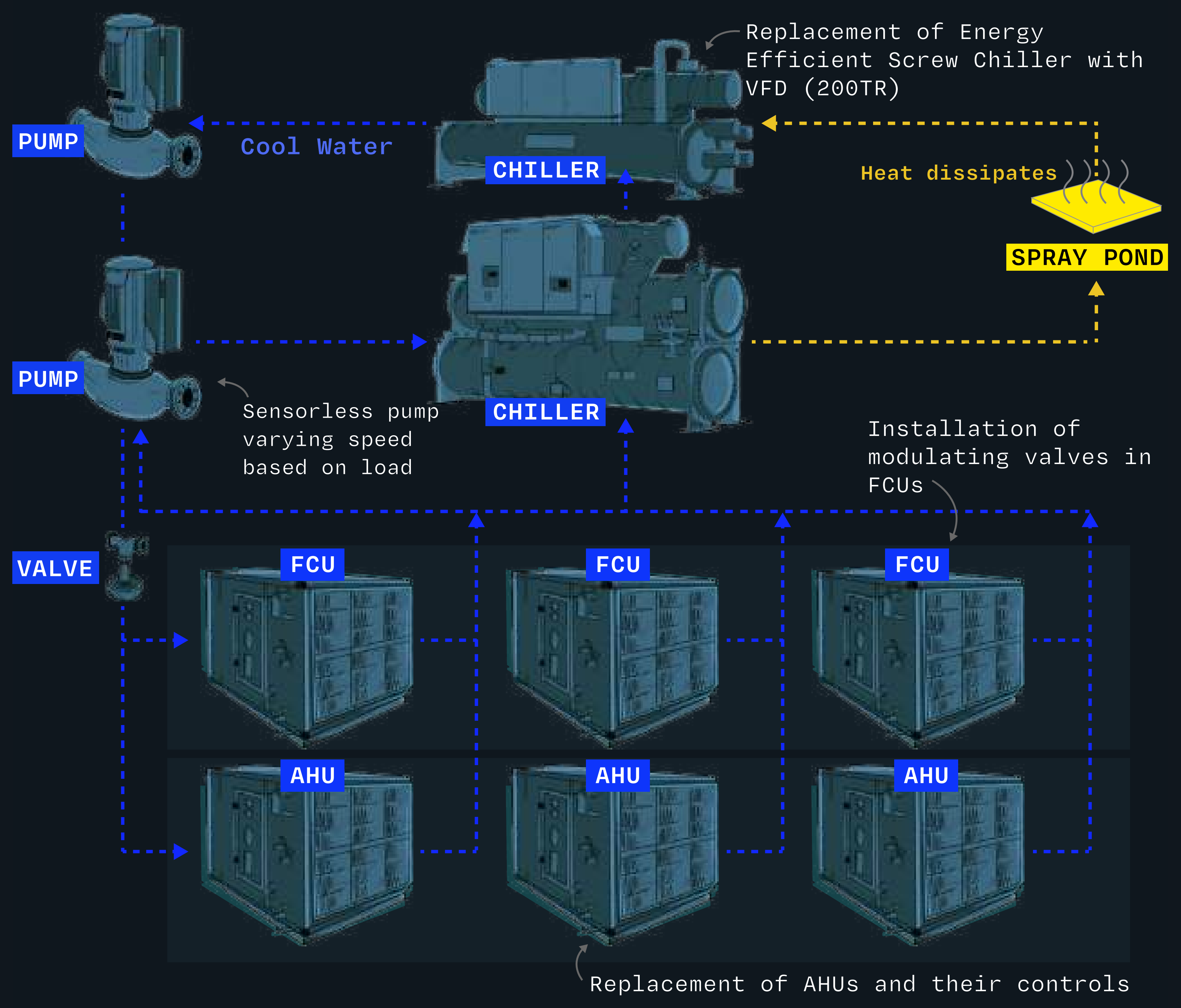
[Adapted from source: Integrative Design Solutions Private Limited]

EXHIBIT 45: The retrofit measures included passive cooling measures like upgradation of the single glazed windows with a high performance low-e glazing, and installation of over-deck roof insulation



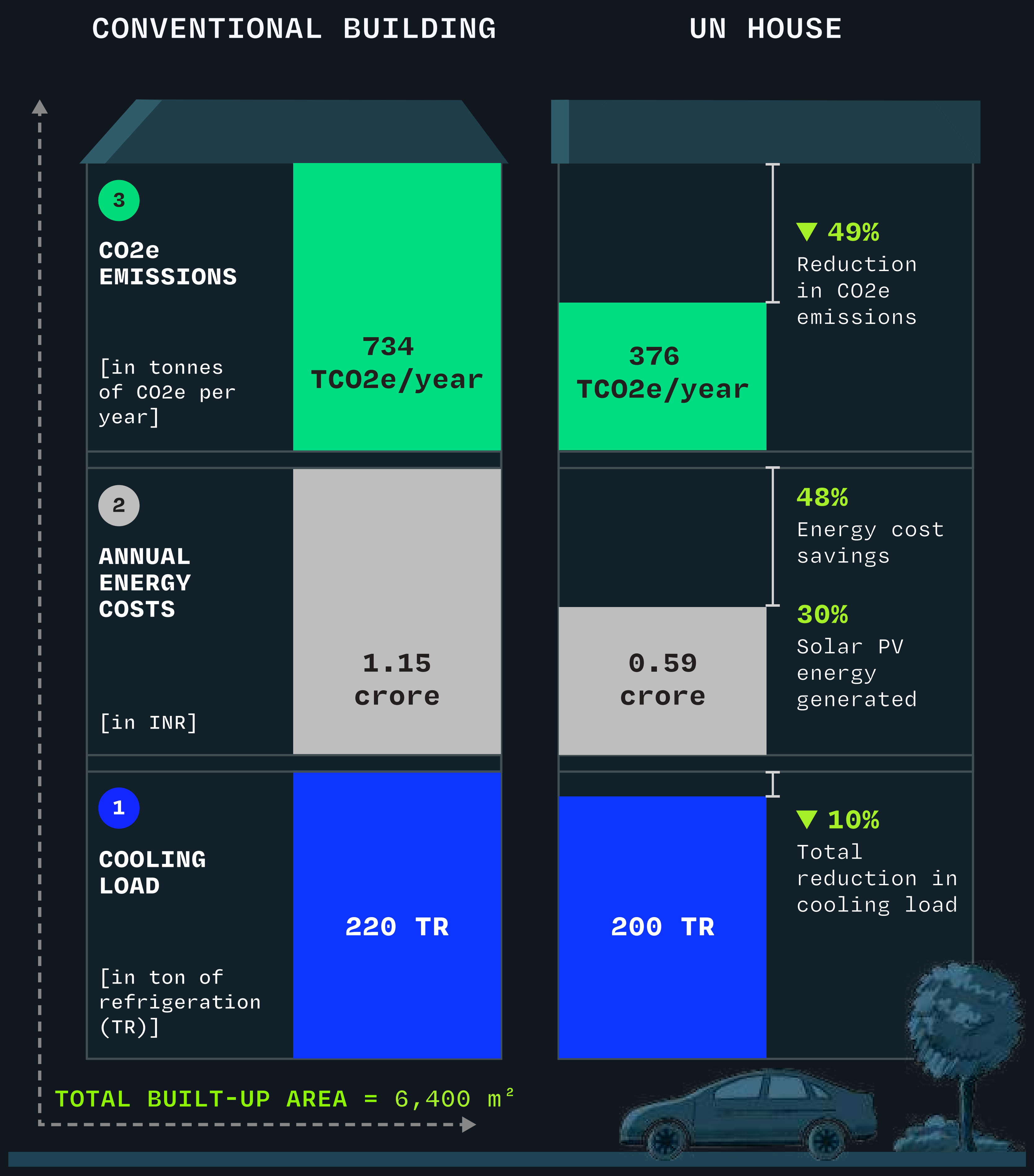
[Adapted from source: Integrative Design Solutions Private Limited]

EXHIBIT 46: The active cooling measures include the replacement of CFL lights with LED lights, and replacement of existing HVAC systems with high performance chillers and AHUs.



[Adapted from source: Integrated Design Solutions Private Limited]

EXHIBIT 47: Energy performance of UN House building



[Source: Integrative Design Solutions Private Limited]

KEY LEARNINGS

Application of passive cooling solutions and efficient equipment can be possible to a larger extent, even in the case of heritage buildings, which usually have lack of space, and access for implementing such solutions. Another example includes the Godrej Bhawan in Mumbai, which set the tone for retrofitting heritage buildings with efficient appliances and passive solutions back in 2010. Majority of buildings used by public and non-governmental organisations can utilise the learnings from these case studies to reduce their energy demand and costs attributable to energy use.

ES
1
2
3
4
5
6
7
8

EXHIBIT 48: Apollo Hospital, Madurai
[Image credit: MedicalTrip[92]]

CASE 8

Project Virya by Apollo Hospitals Limited

Launched in September 2021 in a partnership between Apollo Hospitals and Smart Joules, an Energy Service Contracting (ESCO) company, Project Virya aims to save 235 million kWh of energy and reduce 290,000 tonnes of CO_2 emissions in a 10-year time frame. This ambitious goal is being achieved through system design enhancements, investments in best-in-class energy efficient equipment, digitization of energy and related equipment and systems, intelligent data-driven automation of operations, training of key personnel, and careful ongoing operations and maintenance management.

Retrofits in Apollo hospitals	IMPACT CREATED
Energy savings	251 Lakh kWh
CO2 emissions avoided	29.7 tonnes
Diesel saved	489,679 litres
PNG saved	200,085 SCM

The energy efficiency retrofits in Apollo hospitals included interventions like new ultra efficient energy efficient chillers, variable speed pumping systems, automated condenser tube cleaning systems, low approach cooling towers, LED Lights, BLDC Fans, modulating valves & VFDs for AHUs, deep instrumentation with intelligent energy monitoring, analysis, and intelligent control technology.

The other interventions deployed in the hospitals under this project included heat pumps for hot water generation to transition from diesel and gas-based heating to electric heating, revamped laundry systems with new efficient electrical heating systems. Below is a snippet of the impact created through this project, through retrofits in more than 15 hospitals in the group.

The transformation of the market for adoption of energy efficient technologies in the Indian buildings can be boosted with the financial models like ESCO as shown in the case study, and other models like Energy-as-a-Service, On-Bill Financing, Bulk Procurement, etc.[93], which helps the building owners/ developers to avoid capital costs for high efficiency technologies. These innovative business models can also help the adoption of low-energy cooling systems or Not-in-Kind Cooling systems, defined in India Cooling Action Plan, which aim at providing enhanced environmental benefits.

CHAPTER 6

Consumer Scale: Leveraging Behavioural Nudges and Awareness to Reduce Carbon

Individuals and households can adopt a variety of measures to optimise their energy consumption.

Two levers available at the household level are a) Buying choices towards energy saving household equipment, and b) Use patterns to save operational energy. Modest behaviour adjustments can yield substantial energy savings over time, help reduce home energy bills, lower carbon emissions and ease pressure on the power grid. Residential energy demand can be further reduced through "structural" investments, including upgrades to more energy-efficient appliances and retrofits to existing household equipment. Appropriate policy interventions and programmes can be designed to promote sustainable changes in behaviour and encourage investments in structural improvements.

The ease and speed with which behavioural interventions can be implemented mean that countries are able to meet their greenhouse gas emissions targets sooner, and at lower cost, thereby accelerating their energy transition and reducing the overall impact on the climate. Drawing on data from programmes that have been implemented in the United States,[94] It is possible to compare the efficacy of behavioural versus "structural" energy-efficiency programmes according to their cost per dollar of climate damage avoided, as well as the average annual number of participants involved in each programme. Structural programmes typically involve measures such as comprehensive assessments of home energy performance as well as incentives for retrofits or the installation of more efficient heating and cooling systems.

Energy labels as market shaping tools for energy-efficient models are also widely practised. Behavioural programmes use levers such as home energy reports, high bill alerts or home energy audits.

India has shown global leadership in bringing the power of individual action to the mainstream climate narrative through Mission LiFE. It envisions a shift from use and dispose economy to circular economy, by driving individual action around conscious consumption and resource utilisation. By leveraging the potential of social networks to influence social norms about climate, LiFE seeks to create a global network of individuals dubbed Pro-Planet People (P3). The P3 community is expected to have a shared commitment to climate, achieved through adoption and promotion of environmentally friendly lifestyles.[95] The initial documentation included about 75 LiFE actions across 7 categories which were specific, easy to practice and non-disruptive.

Mission LiFE is an acknowledgement that awareness generation and nudge are powerful tools of change as they enable direct action by individuals. The transformation achieved through awareness and nudge are long-lasting and cost-effective in terms of impact delivered per dollar spent.[96] Awareness and nudge campaigns are also highly replicable and scalable. The buildings sector can benefit immensely from the application of nudge to drive adoption of climate-conscious behaviour and solutions.

EXHIBIT 49: LiFE recommends simple energy saving actions to individuals and communities

- Use LED bulbs/tube-lights
- Use public transport whenever possible
- Take the stairs instead of an elevator whenever possible
- Switch off vehicle engines at red lights and railway crossings
- Use bicycles for local or short commutes
- Switch off irrigation pumps after use
- Prefer CNG/EV vehicles over petrol/diesel vehicles
- Use carpooling with friends & colleagues
- Drive in the correct gear; keep your foot off the clutch when not changing gears
- Install a solar water or solar cooker heater on rooftops
- Switch off appliances from plug points when not in use
- Use biogas for cooking and heating needs
- Keep temperature of Air Conditioners to 24 degrees Celsius
- Prefer pressure cookers over other cooking utensils
- Keep your electronic devices in energy-saving mode
- Use smart switches for appliances which are used frequently
- Install community earthen pots for cooling water
- Defrost fridge or freezer regularly
- Run outdoors instead of on a treadmill

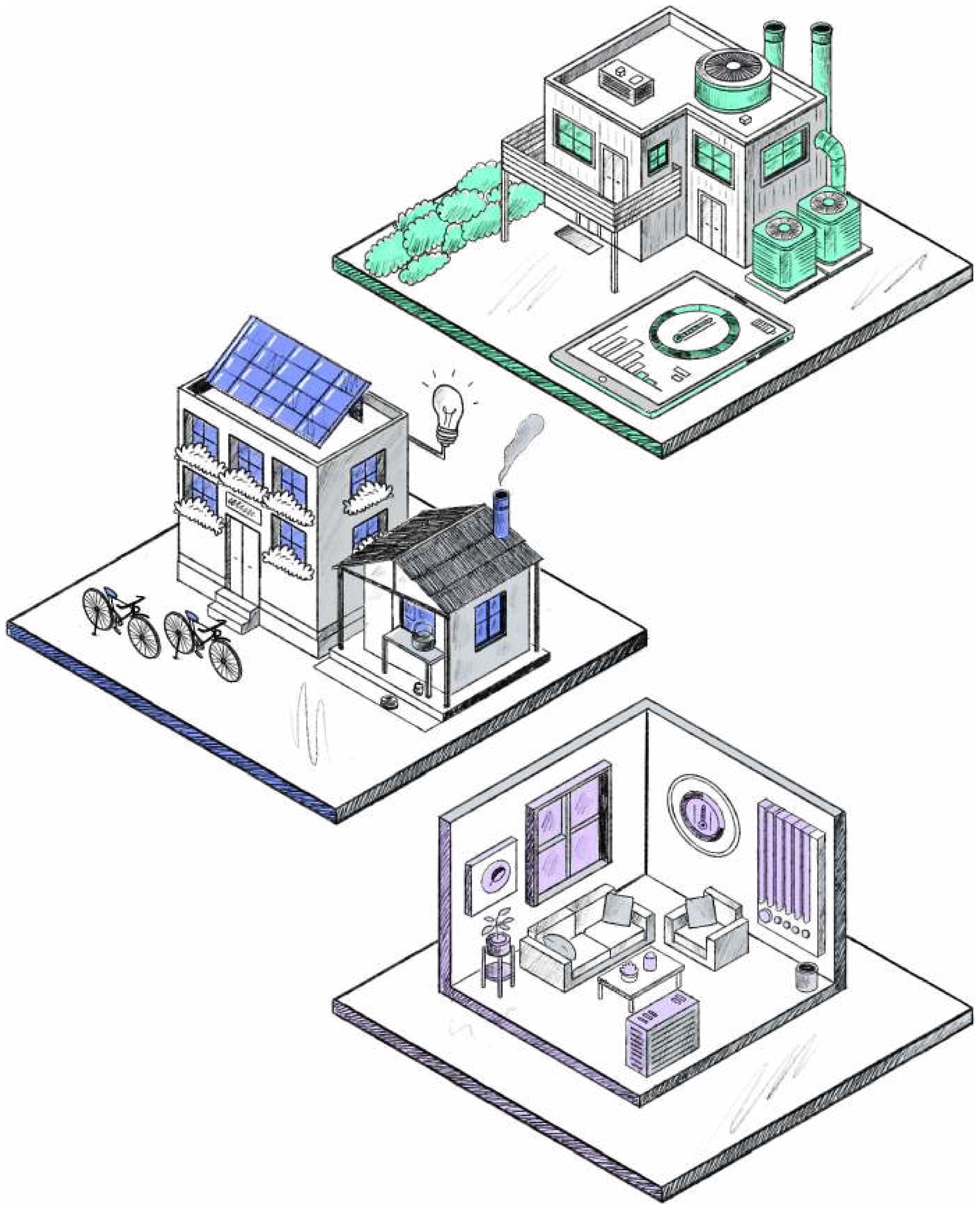
[Source: Niti Aayog[97]]

6.1 Big impacts of behavioural interventions

In the United States, potential energy savings from behavioural interventions in the residential sector are estimated at between 16 per cent and 20 per cent of home energy demand.[98] In this region, the greatest potential savings come from regulatory adjustments to default temperatures for heating and cooling, as well as from interventions in hot water use. These types of behaviour changes can be facilitated through feedback mechanisms and smart devices.

European countries have also found the potential savings to be sizable. Ireland, for example, estimates that modest changes in behaviour, such as adjustments to indoor temperature settings, would lead to significant reductions in energy use: 2.4 TWh per year in the case of residential buildings alone, and 6.5 TWh overall[99] when commercial and public buildings are included. This would enable the country to lower its total energy consumption by about 5 per cent.[100]

India estimates the potential for energy savings through behavioural interventions to be in the range of 3.4 to 10.2 TWh per year by 2030,[101] which translates to about 1.8 to 5.3 Mt CO_2 of avoided greenhouse gas emissions per year. While reaching full potential requires planning for the next ten years, deploying well-known programmes such as home energy reports to a subset of Indian states today could deliver energy savings of 720 to 2140 GWh per year within two years.



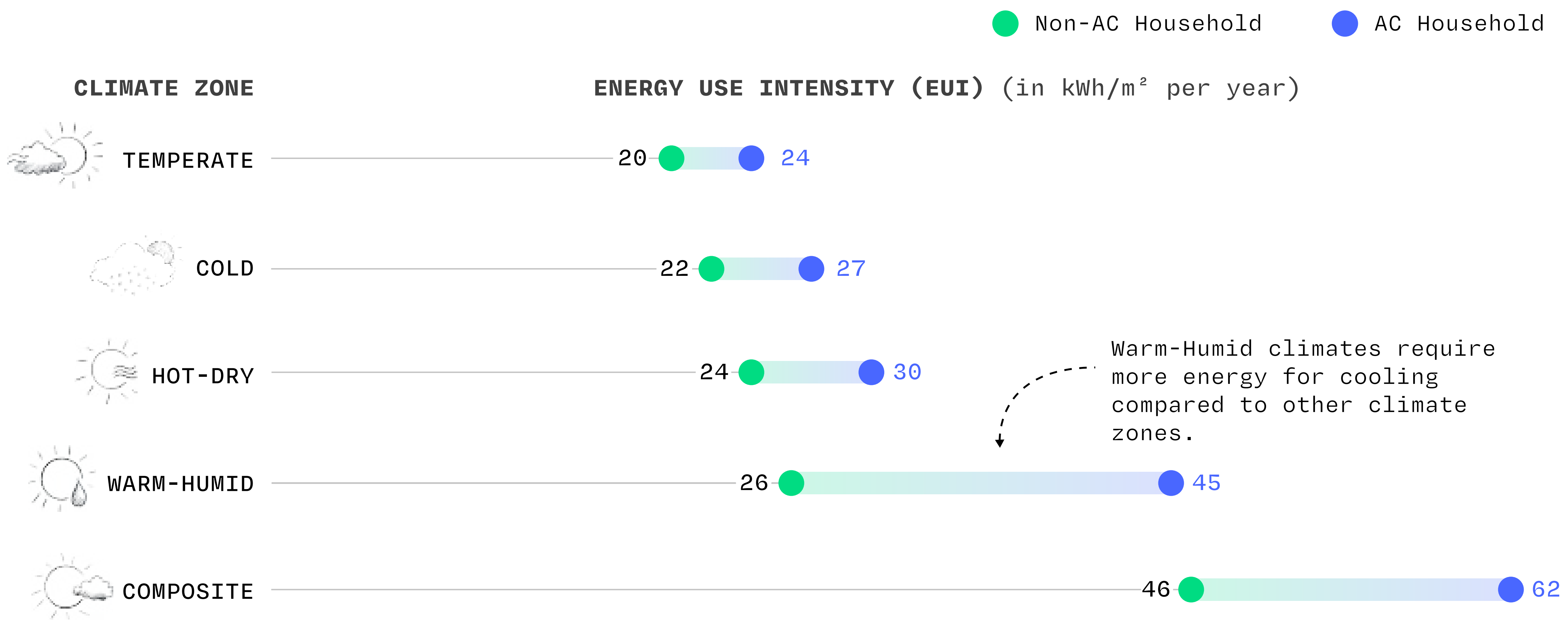
6.2 Cost of mitigation in residential homes

As noted, the residential homes use about 70 per cent of buildings sector electricity consumption. There are readily available energy-efficient substitutes available to make a big dent in operational carbon from the residential buildings sector, as appliances, lighting and equipment used for cooling and heating are responsible for more than 80 per cent of electricity consumption in homes. Within this energy intensity split, air-conditioning for thermal comfort contributes about 40 per cent of energy demand and use.

Indeed, just the structural programmes to nudge consumers to purchase energy-efficient appliances is a big lever for building decarbonisation, with compounding impact through behavioural nudges for judicious use. The upfront cost of energy-efficient appliances is certainly more, but energy savings and lower electricity bills ensure quick payback periods and make interventions cost positive over appliances' lifecycle. Another analysis pointed out that about 70 per cent emissions from residential homes can be effectively mitigated with solutions that are cost positive today or will become cost positive by 2030.[102]

These behavioural interventions have proven to deliver remarkable results, as also shown by India's Star Labelling (S&L) Programme. In 2021-22, the S&L programme led to a reduction in emissions – approximately 160 million tonnes, which is 16 per cent of the annual national target, and resulted in savings amounting to approximately INR 94,000 crore.[103] One must also note that these impressive figures have been achieved despite the share of high energy efficiency air-conditioners remaining low. The cost of energy efficient appliances also falls about 2-3 per cent every year, further making it attractive for the customers. The results of the S&L programme prove that improvement in awareness building to shift attention from upfront cost to lifecycle cost (upfront + energy + maintenance cost) offers a highly impactful lever for decarbonisation of operational energy through energy-efficiency in the residential sector.

EXHIBIT 50: Airconditioning is responsible for the increase in energy use intensity in residential homes



[Source: CLASP (2021)[104]]

EXHIBIT 51: T77 Precinct, Bangkok

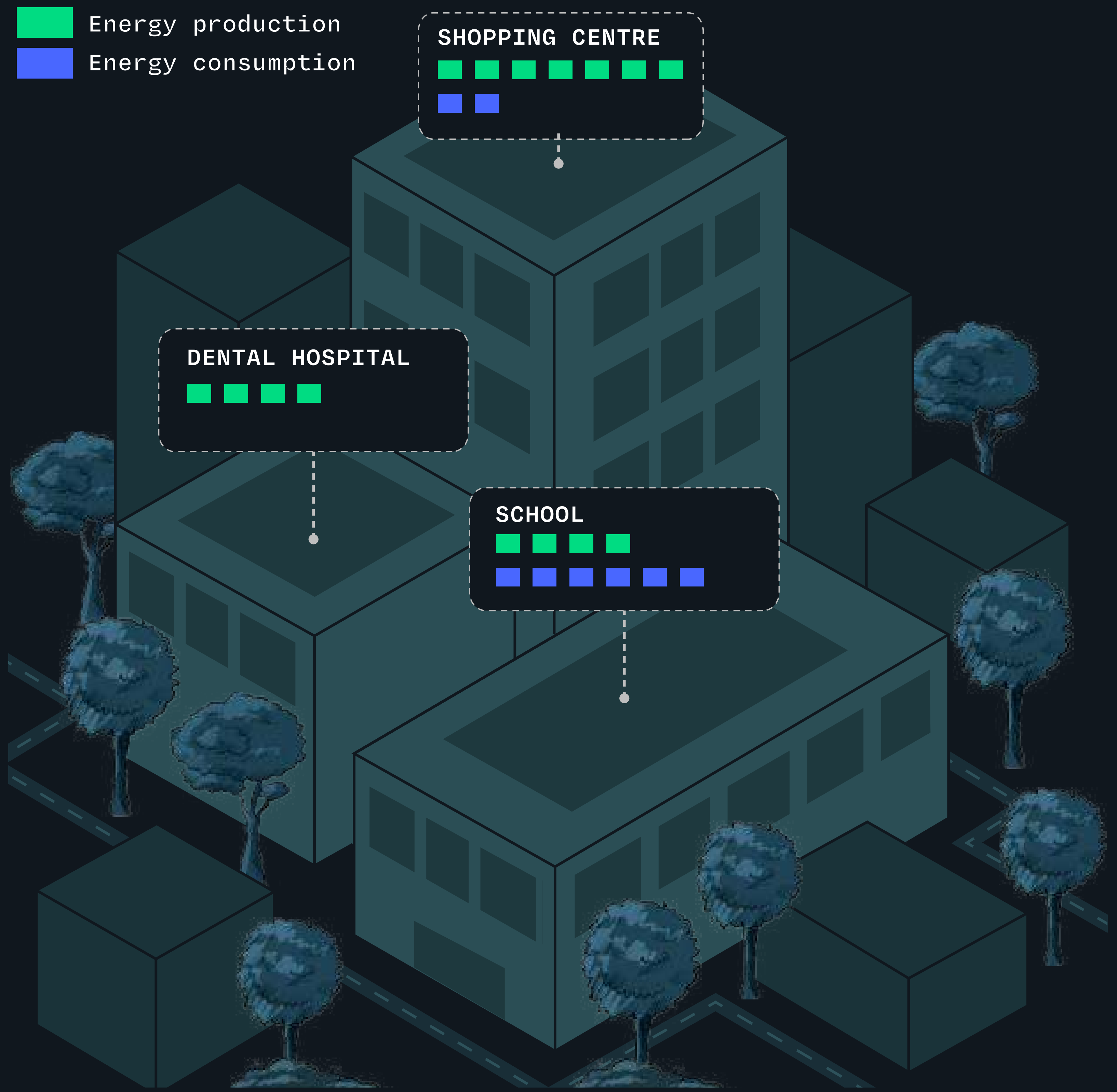
[Image credit: BPCG Group]

CASE 9

Power Ledger: A platform for prosumers

Technology can be leveraged to shape user decisions about energy. Power Ledger is a powerful example of creating a network of energy users on an energy trading platform. Rolled out in 2018, Power Ledger has enabled peer-to-peer (P2P) trading in the T77 precinct of Bangkok, Thailand by educating the consumers on the benefits of using clean energy and maximising energy efficiency in their households. As a result of the platform, the total solar generation capacity of the T77 project has increased from 2.8MWh daily solar generation across 4 buildings to 4.2MWh across 7 buildings. The additional buildings within the project include the multi-tenant residential complexes Hasu haus and Mori haus and O77, a smart office building.

EXHIBIT 52: **P2P energy trading use cases in T77 include residential complexes, smart office buildings, shopping centers, schools and hospitals**



[Adapted from source: Power Ledger[105]]

Trading of solar energy continues across the Habito Shopping Centre, Bangkok Prep School, dental hospital, and the Juristic Persons of Park Court Apartment complex. The platform enables BCPG, Thailand (Renewable energy generation company) to monitor energy generation and transactions between the participating buildings. It also provides the ability to generate invoicing for settlement and a summary of the trading position for individual participants. Power Ledger was awarded the Innovative Power Technology of the Year – Thailand at the Asian Power Awards, 2019 and the Best Clean Energy Community Solutions, South East Asia, 2022.

INDIA IN FOCUS - KEY LEARNINGS

Engaging the consumers in the buildings to solicit climate actions has been quite difficult due to differences in social and economic aspects of individual users. This case has shown that presenting the consumers with the in-hand benefits they can receive with technology interventions, can lead to accelerated participation in such climate actions. Creating specific interventions and sensitization to the consumers still require efforts in the form of continuous communication and engagement until the necessary number of users are on-board.[106]

A pilot project with the Government of Uttar Pradesh has demonstrated the feasibility of PowerLedger's platform to trade energy from rooftops with solar power to neighbouring households/buildings. This has enabled the definition of the network tariff that will support the wider rollout of P2P electricity trading across the state. As a result, UPPCL was able to understand the impacts that P2P trading has on the electricity distribution network.

Following the successful pilot led by PowerLedger, the Uttar Pradesh Electricity Regulatory Commission (UPERC) issued a tariff order, directing all the utilities in the state of UP to implement P2P energy trading. In achieving this, affordable electricity can be distributed to the unelectrified population, usually rural parts of the state, improving the economic welfare for the citizens of UP.

CASE 10

Leveraging mass medium - Japan's education drive for NZEB solutions

A successful story on education and awareness emerged from Japan, where the Ministry of Environment; Ministry of Land, Infrastructure, Transport and Tourism, and Ministry of Economy, Trade, and Industry (Agency for Natural Resource and Energy) joined forces to promote a climate-friendly building policy, producing Building Energy Conservation Law in 2015. The three ministries conduct joint outreach on net zero energy buildings (NZEB) to different audiences via different types of media - maximising the communication effect with joint budgets. The programme also helped the citizens to understand clearly the elusive concepts of NZEB, Passive Cooling, Nature-based solutions, etc.

EXHIBIT 53: Three Japanese ministries conduct joint outreach on NZEB to different audience via different types of media

[Image credit: Ministry of Land, Infrastructure and Transport, Ministry of the Environment, Ministry of Economy, Trade and Industry, Government of Japan]

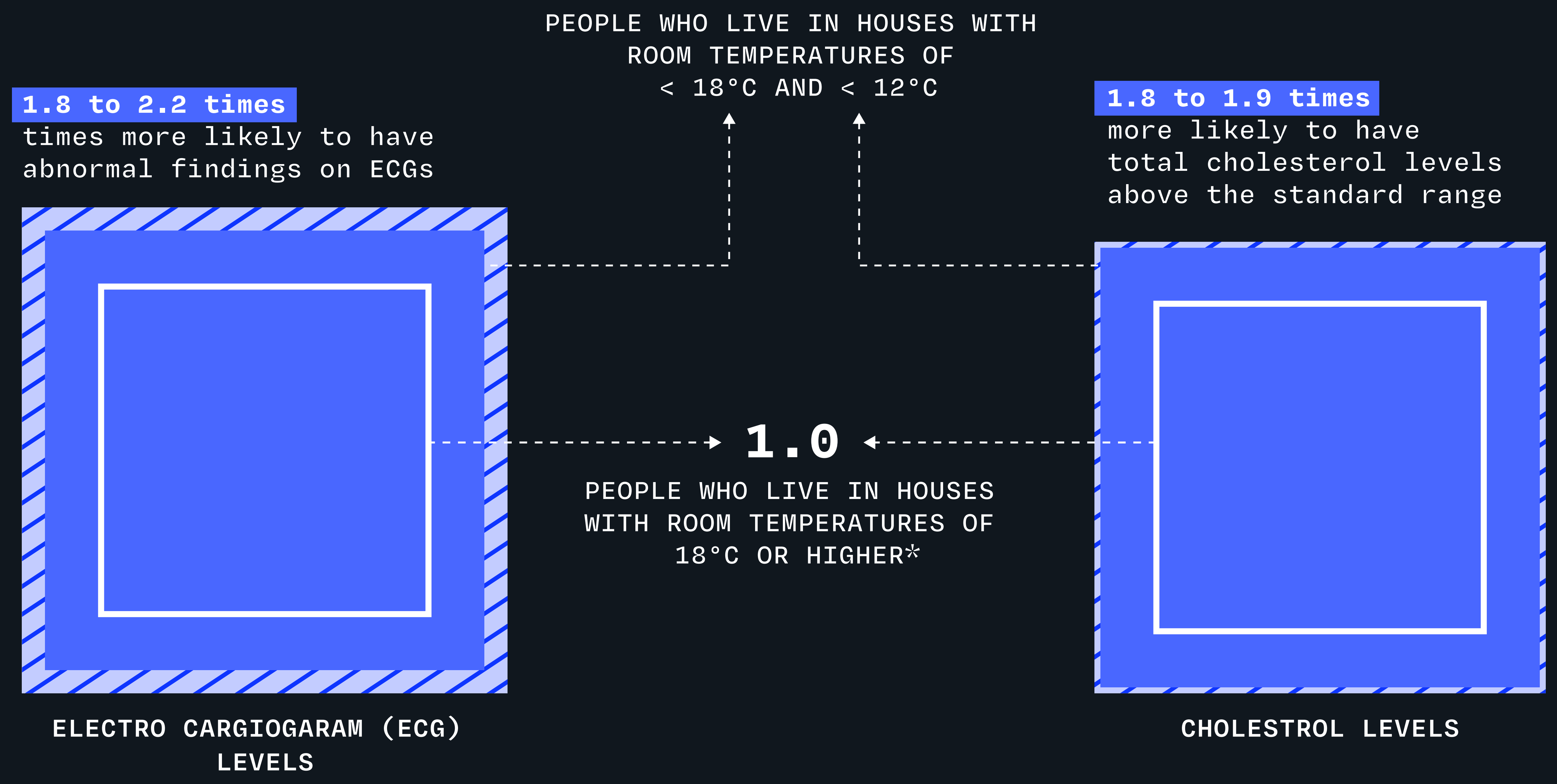
A joint labelling system for NZEBs, which guarantees performance of passive, active and renewable design was launched by these ministries to induce private sector participation in clean energy programmes and use this label to promote and elevate their value propositions in the market.

The outreach materials used by the ministries emphasise on showcasing the know-how on measures to reduce energy bills and make a net zero home in the country. All this is done with simple graphics to communicate how much reduction is possible with passive envelopes, efficient appliances, and solar PV power generation.

EXHIBIT 54: A comprehensive energy labelling programme for NZEB buildings in Japan

[Adapted from source: Ministry of Land, Infrastructure, Transport and Tourism, Japan]

EXHIBIT 55: The publication cartoons also showcased the health benefits of energy-efficient practices such as impact on health due to low operational AC setpoints at household level.



*ECG: 1.0 as reference value for occurrence of abnormal findings on ECGs
*CHOLESTROL: 1.0 as total cholestrol in the reference range

[Adapted from source: Ministry of Land, Infrastructure, Transport and Tourism, Japan]

INDIA IN FOCUS - KEY LEARNINGS

In India, existing programmes like BEE Star Labelling for appliances, Star Rating Program for Commercial Buildings quantify the energy performance and communicate with the users on selecting efficient appliances or commercial spaces. There is a gap which exists in how the individual aspects of decarbonisation (Passive design, Efficient active systems, Renewable energy systems and even embodied carbon) can be communicated to the users in understanding the performance of the built environment for better decision-making.

A large variety of guidelines have been developed in India for education of professionals working in the building design and construction on decarbonisation of the built environment. The current gap, as related with this case study of Japan, is the unavailability of communication materials or mass media content, which can educate the common public, and the informal workforce employed in the building construction sector. The continuous communication and engagement with the public at large on decarbonisation measures like passive design, energy efficiency, renewable energy through illustrations, videographic and comic forms has proven to be effective in pushing the developers and property owners to achieve better performance.

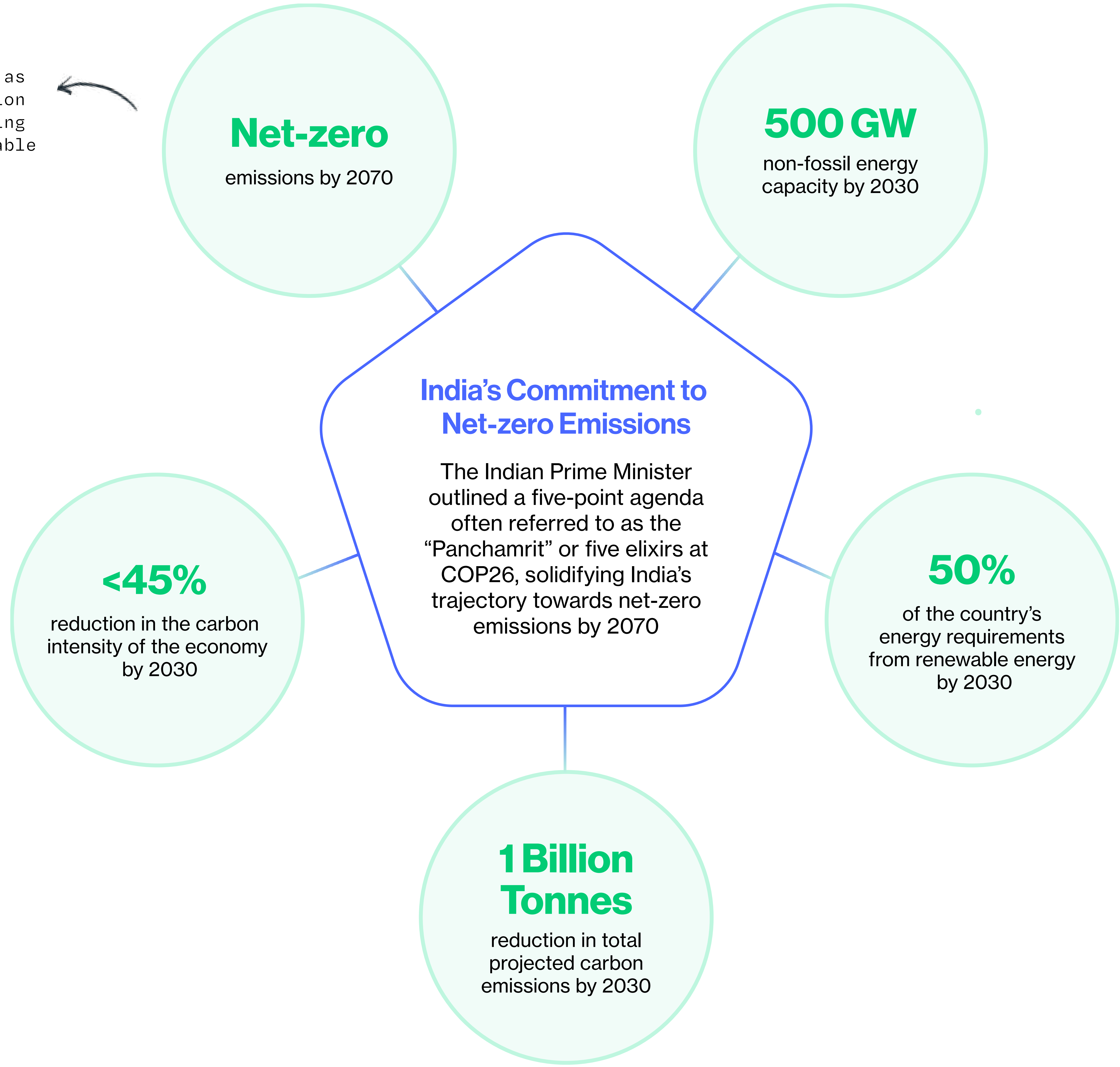
CHAPTER 7

Creating Decarbonisation Incentives through Policies and Regulations

7.1 India International Commitments

These ambitious targets serve as a roadmap for India's transition to a low-carbon economy, placing significant emphasis on renewable energy and energy efficiency.

EXHIBIT 56: India's 'Panchamrit' strategy to achieve net-zero emissions



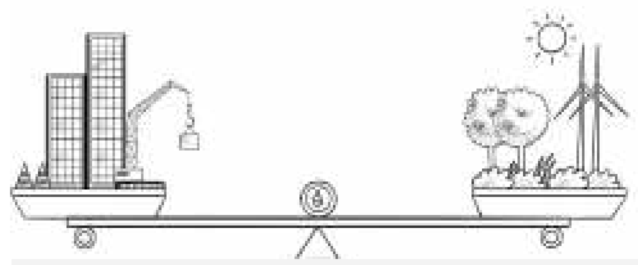
[Source: Authors' adaptation and analysis]

India has made international commitments that aligns with the country's trajectory of achieving net-zero emissions, particularly through Nationally Determined Contributions (NDCs), Sustainable Development Goals (SDGs) and Kigali Amendment to Montreal Protocol. India's NDCs emphasise reducing the emissions intensity of its GDP by 45 per cent by 2030 compared to 2005 levels by increasing non-fossil fuel-based energy capacity to 50 per cent and creating additional carbon sinks through afforestation. India's commitment to the SDGs supports its building decarbonisation goals through key initiatives like Goal 7 (Affordable and Clean Energy), promoting renewable energy and energy-efficient technologies in buildings. Goal 11 (Sustainable Cities and Communities) encourages green construction and retrofitting, while Goal 13 (Climate Action) integrates energy efficiency and decarbonisation into building policies. India through ratification of the Kigali Amendment to the Montreal Protocol will phase down Hydrofluorocarbon (HFCs) with cumulative reduction of 85 per cent in 2047. During the G20 Presidency in 2023, through New Delhi Leaders' Declaration India endorsed the efforts of efforts to triple renewable energy capacity globally and the voluntary action plan on Doubling the Rate of Energy Efficiency Improvement by 2030.[107]

7.2 Policy and Regulatory Interventions

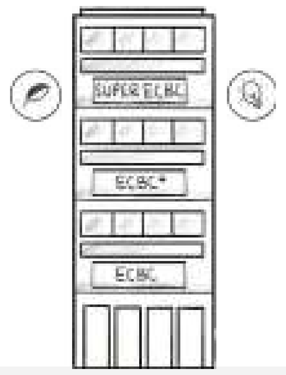
This section outlines the policies and regulatory interventions that facilitate the decarbonisation of buildings.

The Energy Conservation Act enacted by the Ministry of Power provides a legal framework for promoting energy efficiency and conservation across various sectors, including buildings. It led to the creation of the Bureau of Energy Efficiency (BEE), which plays a key role in implementing policies and setting standards to improve energy performance.



Environmental Impact Assessment (EIA)

EIA is a process that evaluates the potential environmental effects of a proposed project or development, considering its interrelated impacts on socio-economic factors, culture, and human health. To strengthen energy efficiency measures, the standard Environmental Clearance conditions for Building and Construction projects, as well as Townships and Area Development projects, require the project proponent to comply with the Energy Conservation Building Code (ECBC) or ECBC-R, as prescribed by the Bureau of Energy Efficiency (BEE) or the respective state government.

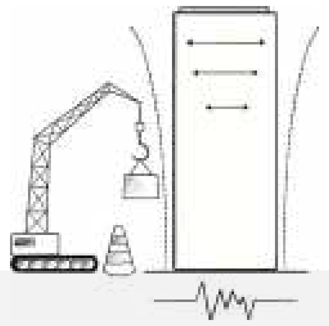


Energy Conservation Building Code (ECBC)

The Energy Conservation Building Code (ECBC), developed by BEE, sets minimum energy performance standards for commercial buildings. The latest version, ECBC 2017, includes low energy cooling systems and establishes three categories of energy performance for building i.e. ECBC, ECBC+, and Super ECBC, with increasing efficiency levels. ECBC compliant building achieves around 25 per cent energy savings, an ECBC+ building offers approximately 35 per cent savings, and a Super ECBC-compliant building can deliver energy savings of 50 per cent or more compared to conventional buildings.[108]

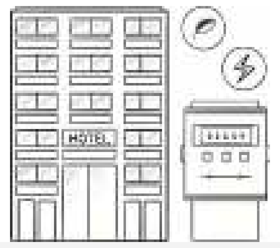
Eco Niwas Samhita

The Energy Conservation (Amendment) Act, 2022 came into effect on 1 January 2023. The amendment extends the Act's scope to cover residential buildings, empowering the central and state governments to notify the code for such structures. ENS Part I focuses on improving the energy efficiency of the building envelope in residential buildings by setting performance standards for walls, roofs, and windows and ventilation. ENS Part II addresses energy efficiency in electro-mechanical systems and promotes the integration of renewable energy in residential buildings. It provides recommendations for energy-efficient appliances and systems, such as lighting and water heating.



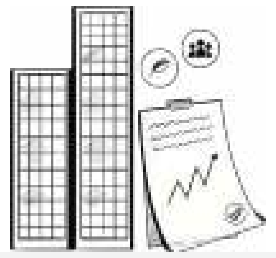
Model Building Bye-Laws (MBBL) 2016

The Ministry of Housing and Urban Affairs has released the model building bye-laws, which gives local governments the framework they need to control building construction. They address issues such as coverage, height, architectural design, and disaster preparedness measures such as earthquake and fire. As of now, 22 out of 36 states and union territories have updated their bye-laws to coincide with MBBL 2016.[109]



National Building Code (NBC)

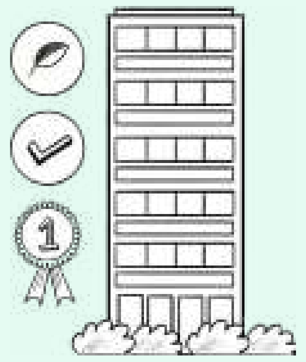
The National Building Code (NBC) 2016, developed by the Bureau of Indian Standards (BIS), provides guidelines for building design and construction. Part 11 of the NBC focuses on sustainability and energy efficiency, with specific recommendations for the efficient use of resources, environmentally friendly construction practices, and energy-saving measures. Many states have incorporated the NBC guidelines into local construction codes.[110]



Business Responsibility and Sustainability Reporting (BRSR)

Securities and Exchange Board of India (SEBI) mandates the top 1,000 listed companies in India to publish the BRSR report as an integral part of the company's annual report. BRSR requires the company to respond to nine core categories, aligned with the principles outlined in the National Guidelines for Responsible Business Conduct introduced by SEBI.

7.3 Voluntary and market-based mechanisms

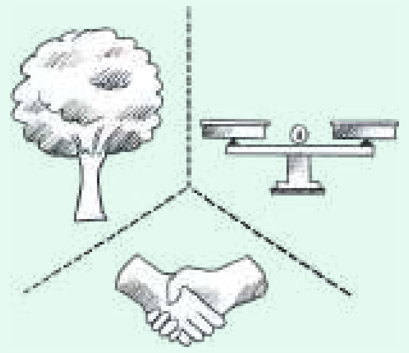


Energy/Green building rating system

Green Building Rating Systems, such as BEE star labelling for buildings, Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environmental Design (LEED), Excellence in Design for Greater Efficiencies (EDGE) and Indian Green Building Council (IGBC), assess buildings based on their environmental impact, energy efficiency, and sustainability.

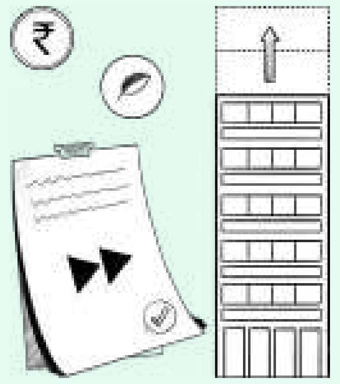
Perform Achieve and Trade (PAT) scheme for hotels

The PAT Scheme, implemented by BEE, is a market-based mechanism aimed at improving energy efficiency in energy-intensive sectors, including commercial buildings like hotels.



Environmental, Social, and Governance (ESG)

ESG framework reporting pushes businesses to adopt environmentally responsible practices, which include reducing the carbon footprint of buildings, improving energy efficiency, and integrating renewable energy.



Government incentives

State and city governments offer various incentives to promote sustainable buildings. Urban Local Bodies of Pune and Hyderabad offer Property tax rebates of up to 10 per cent for buildings with green building certifications like GRIHA or LEED. States like Maharashtra, Haryana, and Punjab offer additional Floor Area Ratio (FAR) or Floor Space Index (FSI) for buildings that are designed as green buildings, thereby allowing developers to build more space while adhering to sustainability standards. Reduced permit fees decrease the cost of obtaining permits for sustainable projects, while fast-track approvals accelerate the regulatory approval process.

7.4 Future policy implementation imperatives

Although India has many innovative regulatory, voluntary, and market mechanisms enabling the decarbonisation of buildings, the actual implementation of energy efficiency in new and existing buildings remains low.

The following suggestions can help strengthen policy implementation and accelerate decarbonisation in the building sector:

1. **Focus on performance-based codes rather than design intent:** Shifting the emphasis from design guidelines to actual performance outcomes requires robust benchmarking of building performance, particularly energy use in commercial and residential typologies. This approach ensures that buildings meet energy efficiency targets in real-world conditions, rather than merely complying with design standards, thus driving better energy performance and reduced emissions.

2. **Streamlining and simplifying compliance checks and building approval processes:** Simplified processes make it easier for building proponents to adopt energy-efficient designs by reducing administrative hurdles. Streamlining approvals will lower the barriers to entry, encouraging more developers to incorporate sustainable practices and accelerating the decarbonisation of the building sector.

3. **Understanding building load profiles and occupant usage patterns:** A deeper understanding of how energy is consumed in buildings will enable the effective deployment of Demand Side Management (DSM) and Demand Response (DR) programs. This can lead to more efficient energy use by adjusting demand to match supply, reducing peak loads, and contributing to overall energy savings and emissions reductions.

4. **Development and implementation of a carbon market in India:** Integrating the building sector into India's emerging carbon market will incentivize the reduction of carbon emissions by allowing the trade of carbon credits. This creates financial incentives for developers to build and retrofit buildings with low-carbon technologies, contributing significantly to the decarbonisation efforts.

5. **Using innovative awareness and capacity-building methods like gamification:** Gamification can engage decision-makers, developers, designers, and end-users in more interactive ways, enhancing their understanding of energy-efficient practices. This approach can help drive behaviour change and wider adoption of sustainable building technologies by making learning more engaging and practical.

6. **Promoting not-in-kind cooling technologies for space cooling:** Implementing advanced cooling technologies such as district cooling, vapour absorption systems, solar thermal air-conditioning, tri-generation, evaporative cooling, and thermal storage can drastically reduce energy consumption. These technologies offer energy-efficient alternatives to traditional vapour compression-based air-conditioning, lowering emissions and contributing to building decarbonisation.

7. **Implementation of grid-interactive buildings and blockchain-based peer-to-peer energy trading:** Designing buildings to interact with the grid and allowing for peer-to-peer energy trading using blockchain technology will enhance energy efficiency. Such systems can optimise energy use, balance supply and demand in real time, and encourage the adoption of renewable energy sources, pushing forward the decarbonisation agenda.

These policy measures and technological interventions will drive substantial improvements in energy efficiency and sustainability in India's building sector, accelerating the country's journey toward decarbonisation.

CHAPTER 8

Conclusion

The choices made for the built environment will play a huge role in India's decarbonisation journey.

The report showcases the solutions that can address embodied and operational carbon emissions from India's built environment at four different scales: urban, material and design, building and consumers. Although the theoretical knowledge about these solutions is easily available, adoption remains the key bottleneck for the sector as perceived and real challenges with regards to cost, implementation and performance remain. As the report shows, over the last few years, several low-carbon options have become cost-competitive and with little effort can be integrated into existing building and construction practices. The engagement within the stakeholder ecosystem can provide the crucial impetus for making large scale adoption a reality.

Impact of proposed strategies on carbon reduction

The cumulative impact of urban, material and design, building and consumer scale solutions featured in the report can lead to a total mitigation of 1,843 million tonnes of CO2e emissions by 2050. This is about 60 per cent of the emission reduction scenario (~3000 million tonnes) needed to put the sector on a net-zero pathway. Within this, the residential buildings have the highest potential for mitigation, accounting to 1,285 million tonnes of CO2e emissions, with impact of 79 per cent operational carbon and 21 per cent embodied carbon reduction as compared to business-as-usual scenario.

Implemented at the urban, building and material scale, the passive design solutions can achieve a total reduction of 383 million tonnes of CO2e emissions by 2050 (residential and commercial combined), whereas energy-efficient systems and appliances offer mitigation impact of 540 million tonnes of CO2e emissions. The consumer scale solutions implemented through grid interactive built environment and peer-to-peer trading of energy can lead to reduction of 294 million tonnes of CO2e emissions.

Achieving convergence in buildings sector ecosystem

Implementation of climate resilient and decarbonisation solutions at 4 different scales will require action from a broad array of stakeholders. The urban scale solutions provide a useful backdrop to policymakers and urban planners in thinking about radical and pragmatic urban forms, designs, and affordable interventions for low-income communities to build resilience against increasing climate extremities. At the material and design scale, a huge part of building supply chain ecosystem, including architects, construction players, cement producers and developers needs to be engaged and coordinate to disrupt the status-quo. Transformation in buildings material market will also require business innovation – which is beginning to take place in India. Likewise, the building scale interventions offer direction to builders and construction players in how to plan and integrate technology-driven solutions such as on-site renewable energy and energy-efficient cooling systems, with passive and low-carbon design approaches at different stages of a building's life cycle. The intervention at consumer scale brings it all together as the end-consumer will have to be at the centre of these strategies. Although their influence on the choices made during building construction is minimal, they exert a huge impact on energy consumption during the building use cycle. Through behavioural nudges, awareness building and education, consumers can create the required momentum and acceptance on the demand side which will make a significant difference to decarbonisation efforts.Through analysis of different challenges and contexts, several recommendations emerge for a varied stakeholder base for greater adoption of the proposed solutions and implementation strategies. These recommendations can be suitably prioritised (Exhibit 57) by specific stakeholders as per the impact and degrees of control they have over specific areas.

India has a robust policy framework to incentivise and regulate building sector practices. However, for the entire sector to be on a net-zero trajectory, the report also highlights the future thrust areas that policymakers and industry should prioritise. Specific actions can be taken by different stakeholders to move the needle in the direction of awareness building, informed choice-making and large-scale adoption.

EXHIBIT 57: Prioritisation of actionable recommendations by different stakeholders can lead to building ecosystem convergence

- **Technical Expertise:** Scientific research, engineering, and system design for solutions.
- **Technological:** Simulation and visualisation software, tools for measurement of solutions.
- **Financial:** Investment, costs, and financial incentives to support solutions.
- **Dissemination:** Knowledge and information sharing about solutions.
- **Skilling:** Capability building through training, education, and development programs.

[Source: Authors' analysis and illustration]

Endnotes and Bibliography

1 Madeline Weir, “Rocky Mountain Institute (RMI),” 27 March 2023. [Online]. Available: https://rmi.org/embodied-carbon-101/ [Accessed October 2024].

2 M. M. S. J. Reshma Singh, “Transforming India’s Built Environment,” Lawrence Berkeley National Laboratory, Berkeley, USA, Indian Institute of Science, Bangalore, India, Infosys Ltd., India, 2020.

3 “The Intergovernmental Panel on Climate Change (IPCC),” [Online]. Available: https://www.ipcc.ch/report/ar6/wg3/chapter/chapter-9/ [Accessed October 2024].

4 Simon Elias Bibri, “Compact city planning and development: Emerging practices and strategies for achieving the goals of sustainability,” Developments in the Built Environment, 2020.

5 “A whole-system approach to decarbonizing India's buildings sector,” Lawrence Berkeley National Laboratory, RMI Analysis, 2022.

6 “Barcelona Institute of Global Health,” 09 September 2019. [Online]. Available: https://www.isglobal.org/en/-/el-proyecto-original-de-las-supermanzanas-podria-evitar-cerca-de-700-muertes-prematuras-anuales-en-barcelona [Accessed October 2024].

7 Natalie Mueller, “Changing the urban design of cities for health: The superblock model,” Environment International, 2020.

8 Diana Vidal Yañez, “An urban green space intervention with benefits for mental health: A health impact assessment of the Barcelona “Eixos Verds” Plan,” Environment International, 2023.

9 Ibid.

10 “Ashden,” 2019. [Online]. Available: https://ashden.org/awards/winners/alcaldia-de-medellin/ [Accessed October 2024].

11 “c40knowledgehub,” [Online]. Available: https://www.c40knowledgehub.org/s/article/Cities100-Medellin-s-interconnected-green-corridors?language=en_US [Accessed October 2024].

12 https://lc3.ch/2024/05/28/low-carbon-cement-can-drive-sustainable-development-in-the-global-south-heres-how/

13 A. Kayastha, “The Hindu Business Line,” 16 December 2023. [Online]. Available: https://www.thehindubusinessline.com/economy/indian-economy-to-reach-5-trillion-in-2026-to-catch-up-with-us-in-2072-economist-arvind-panagariya/article67642882.ece [Accessed October 2024]

14 “World Bank Group,” 23 November 2022. [Online]. Available: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099920011222212474/p15743300f4cc10380b9f-6051f8e7ed1147 [Accessed October 2024]

15 Tom Kompas, “The Effects of Climate Change on GDP by Country and the Global Economic Gains from Complying with the Paris Climate Accord,” Earth's Future, p. 1153–1173., 2018.

16 Angela Piccirillo ID, “A review of the climate-related risks facing India, and their economic and social costs,” ODI Literature review, London, 2021.

17 “International Energy Agency” [Online]. Available: https://www.iea.org/energy-system/buildings

18 “National Institute of Urban Affairs,” [Online]. Available: https://niua.in/urban-statistical-profile [Accessed October 2024]

19 “Bureau of Energy Efficiency,” [Online]. Available: https://beeindia.gov.in/en/programmes/buildings-0 [Accessed October 2024]

20 “Organisation for Economic Co-operation and Development,” [Online]. Available: https://www.oecd.org/en/about/programmes/decarbonising-buildings-in-cities-and-regions.html [Accessed October 2024].

21 “Shakti Sustainable Energy Foundation,” [Online]. Available: https://shaktifoundation.in/policy-solutions-for-the-uptake-of-net-zero-energy-buildings-in-india/ [Accessed October 2024].

22 H. Koss, “Built In,” 11 January 2024. [Online]. Available: https://builtin.com/articles/conscious-consumerism [Accessed October 2024].

23 “Lifestyle of Environment,” [Online]. Available: https://www.niti.gov.in/sites/default/files/2022-11/Mission_LiFE_Brochure.pdf [Accessed October 2024].

24 “Press Information Bureau,” 09 November 2022. [Online]. Available: https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/nov/doc2022119122601.pdf. [Accessed October 2024]

25 “Frontline,” [Online]. Available: https://frontline.thehindu.com/environment/how-delhi-record-breaking-heatwave-revealed-climate-vulnerabilities-infrastructure-shortcomings- [Accessed October 2024].

26 A. Mohanty, “Preparing India for Extreme Climate Events,” Council on Energy, Environment and Water (CEEW), 2020.

27 David Eckstein, “GLOBAL CLIMATE RISK INDEX 2021,” German watch E.V, Berlin, 2021.

28 B. Chatterjee, “Hindustan Times,” 20 November 2020. [Online]. Available: https://www.hindustantimes.com/mumbai-news/mumbai-slums-are-6-degrees-celsius-warmer-than-neighbouring-housing-societies-in-october-study/story-wo22fMA4bIUjzvV5OIdamN.html [Accessed 28 October 2024].

29 Bibri (n 4)

30 Urban Climate Lab, Graduate Program in Urban & Regional Design, New York Institute of Technology, 2016.

31 L. Ze Liang, “The relationship between urban form and heat island intensity along the urban development gradients,” Science of The Total Environment, 2020.

32 “The impact of urban form on disaster resiliency: a case study of Brisbane and Ipswich, Australia,” International Journal of Disaster Resilience in the Built Environment, pp. 259-275, 2016.

33 V. Silva, “Urban Form and Energy Demand: A Review of Energy-relevant Urban Attributes,” Journal of Planning Literature, pp. 346-365, 2017.

34 “PRIMER ON URBAN FORM AND GREENHOUSE GAS EMISSIONS,” World Bank City Climate Finance Gap Fund, 2021.

35 Ibid.

36 “Iberdrola,” 2022. [Online]. Available: https://www.iberdrola.com/sustainability/sustainable-cities#:~:text=Leaders%20in%20urban%20sustainability%20*%20Oslo%2C%20leader,third%20in%20the%20'Sustainable%20Cities%20Index%202022' [Accessed October 2024].

37 Eko Nursanty1, “Shaping City Identity: The Role of Built Environment Quality,” in E3S Web of Conferences 533, 2024.

38 “Agence Francaise De Developpement,” 25 July 2019. [Online]. Available: https://www.afd.fr/en/actualites/these-12-indian-cities-are-future-sustainable-urban-development [Accessed October 2024].

39 “NDTV,” 06 June 2024. [Online]. Available: https://www.ndtv.com/mumbai-news/mumbai-civic-body-bmc-introduces-its-first-climate-budget-report-5834336 [Accessed October 2024].

40 P.R. Shukla, “Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,” Intergovernmental Panel on Climate Change., 2022.

41 “C40Cities,” [Online]. Available: https://www.c40knowledgehub.org/s/article/Consumption-based-GHG-emissions-of-C40-cities? [Accessed October 2024]

42 IEA (n 17)

43 “Architecture 2030,” [Online]. Available: https://www.architecture2030.org/old-why-the-built-environment/ [Accessed October 2024].

44 “World Green Building Council,” 2019. [Online]. Available: https://worldgbc.org/advancing-net-zero/embodied-carbon/ [Accessed October 2024].

45 G. P. S. Raina, “Decarbonising the built environment in India,” Royal Institution of Chartered Surveyors (RICS), London, 2023.

46 “Alliance for an Energy Efficient Economy (AEEE),” 28 March 2022. [Online]. Available: https://aeee.in/tackling-embodied-carbon-from-indias-building-sector/ [Accessed October 2024].

47 “International Energy Agency (IEA),” [Online]. Available: https://www.iea.org/energy-system/buildings [Accessed October 2024].

48 “India Cooling Action Plan,” Ministry of Environment, Forest & Climate Change (2019), New Delhi, 2019.

49 “BSI Group” [Online]. Available: https://knowledge.bsigroup.com/products/sustainability-of-construction-works-assessment-of-environmental-performance-of-buildings-calculation-method?version=standard

50 Weir (n 1)

51 Singh (n 2)

52 IPCC (n 3)

53 RMI (n 5)

54 “Insights Strategy Analysis,” September 2023. [Online]. Available: https://www.lasalle.com/wp-content/uploads/2023/09/lasalle-value-of-green-sept-11-2023.pdf [Accessed October 2024].

55 “Mckinsey,” [Online]. Available: https://www.mckinsey.com/industries/engineering-construction-and-building-materials/our-insights/building-value-by-decarbonizing-the-built-environment [Accessed October 2024].

56 "Economic Times," 26 July 2024. [Online]. Available: https://economictimes.indiatimes.com/news/economy/infrastructure/india-to-get-12-new-industrial-cities-to-boost-manufacturing-dpiit-to-approach-cabinet/articleshow/112040871.cms?from=mdr [Accessed October 2024].

57 "C40," [Online]. Available: https://www.c40.org/what-we-do/raising-climate-ambition/accelerator-reports/ [Accessed October 2024].

58 Isglobal (n 6)

59 Mueller (n 7)

60 Yanez (n 8)

61 Yanez (n 8)

62 E. C. Laia Palència, "Report of results of the environmental and health effects of the Superblocks model in Barcelona. Salut Als Carrers (SAC) Project.," Agència de Salut Pública de Barcelona, Barcelona, 2021.

63 "Nature," [Online]. Available: https://www.nature.com/articles/s43017-020-00129-5. [Accessed October 2024].

64 "IndiaSpend", 2023. [Online]. Available: https://www.indiaspend.com/explainers/explained-as-indoor-heat-rises-can-india-turn-to-green-roofs-867308

65 W.C. Li, "A comprehensive study of green roof performance from environmental perspective," International Journal of Sustainable Built Environment, pp. 127-134, 2014.

66 Ashden (n 10)

67 c40knowledge hub (n 11)

68 P. Bhide, "Kubernein Initiative," 13 April 2021. [Online]. Available: https://kuberneininitiative.com/article/integrating-urban-greening-in-city-planning/ [Accessed October 2024].

69 Bureau of Energy Efficiency. Cool Roofs for Cool Delhi: Design Manual. Available: https://shaktifoundation.in/wp-content/uploads/2017/06/cool-roofs-manual.pdf

70 "Indian Institute of Information Technology, Hyderabad, " [Online]. Available: https://cbs.iiit.ac.in/cool-roof-calculator/

71 Prima Madan. 2023. Telangana announces a groundbreaking cool roof policy. Available: https://www.nrdc.org/bio/prima-madan/telangana-announces-groundbreaking-cool-roof-policy

72 "Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector," United Nations Environment Programme, Nairobi. , 2022.

73 Ashok B. Lall, "Low-carbon Resource- Efficient Affordable Housing," Greentech Knowledge Solutions Pvt. Ltd. 2017.

74 P. H. Chetia, "Whole-life carbon analysis of residential buildings in India: Three case studies from Bengaluru (Executive Summary)," Greentech Knowledge Solutions Pvt. Ltd (GKSPL), New Delhi, 2024, August.

75 Nitturu, Kartheek, Pratheek Sripathy, Deepak Yadav, Rishabh Patidar, and Hemant Mallya. 2023. Evaluating Net-zero for the Indian Cement Industry: Marginal Abatement Cost Curves of Carbon Mitigation Technologies. New Delhi: Council on Energy, Environment and Water. Available: https://www.ceew.in/publications/how-can-india-decarbonise-for-net-zero-cement-industry

76 LC3 Initiative (n 12)

77 V. Rawal, "Thermal Properties Database of Building Materials and Technologies, Part-1," Greentech Knowledge Solutions Pvt Ltd., CEPT Research and Development Foundation-CEPT University. 2022, October.

78 S. Maithel, "Improved burnt clay brick masonry: lowering upfront embodied carbon, improving thermal comfort and climate resilience of new housing in the Indo-Gangetic Plains," in Comfort at The Extremes 2023, 2024, January.

79 "Godrej Enterprises", [Online]. Available: https://www.godrejenterprises.com/blog/infra-recycling-concrete-to-curb-emissions

80 Sayali Sandbhor, Sayali Apte, Vaishnavi Dabir, Ketan Kotecha, Rajkumar Balasubramaniyan, Tanupriya Choudhury. AI-based carbon emission forecast and mitigation framework using recycled concrete aggregates: A sustainable approach for the construction industry[J]. AIMS Environmental Science, 2023, 10(6): 894-910. https://www.aimspress.com/article/doi/10.3934/environsci.2023048?viewType=HTML

81 Global Database of Materials and Embodied Carbon: https://circularecology.com/embodied-carbon-footprint-database.html and Indian Database for Embodied Carbon of Materials: India Construction Materials Database of Embodied Energy and Global Warming Potential Methodology Report, 2017, IFC https://edgebuildings.com/wp-content/uploads/2022/04/IFC-India-Construction-Materials-Database-Methodology-Report.pdf

82 "Brydenwood", [Online]. Available: https://www.brydenwood.com/sustainablebuildings/s93384/

83 www.beepindia.org/wp-content/uploads/2013/12/Smart-GHAR_final_0_14.pdf

84 India Energy Statistics. Ministry of Statistics and Program Implementation. 2023. Available: https://www.mospi.gov.in/publication/energy-statistics-india-2023

85 "Compendium of Innovative Emerging Technologies," Ministry of Housing & Urban Affairs, Government of India, New Delhi , 2020, December.

86 "Sageglass", [Online]. Available: https://www.sageglass.com/smart-windows/product-overview

87 "Trane Technologies", [Online]. Available: https://www.trane.com/commercial/north-america/us/en/products-systems/heat-pumps.html

88 "Calmac", [Online]. Available: https://www.calmac.com/how-energy-storage-works

89 "Coral Life", [Online]. Available: https://www.corallife.co.th/

90 "Tracking Clean Energy Progress," IEA , Paris, 2023.

91 Y. M. Dong Zhao, "Construction Cost Decomposition of Residential Building Energy Retrofit," Buildings, 2023.

92 "MedicalTrip", [Online]. Available: https://medicaltrip.in/hospital/apollo-hospital-madurai/

93 A Nain, S. Bhasin, "Making Sustainable Cooling in India Affordable – A Study of Financing Business Models," Council on Energy, Environment and Water, New Delhi, 2022.

94 Hibbard P, "Analysis Group," [Online]. Available: https://www.analysisgroup.com/Insights/publishing/utility-energy-efficiency-program-performance-from-a-climate-change-perspective-a-comparison-of-structural-and-behavioral-programs/. [Accessed october 2024].

95 "NITI Aayog," [Online]. Available: https://www.niti.gov.in/life. [Accessed October 2024].

96 C. Fried, "Should governments invest more in nudging?" ULCA Anderson Review, 2017.

97 "Mission LiFE Brochure", NITI Aayog, New Delhi, 2022. Available: www.niti.gov.in/sites/default/files/2022-11/Mission_LiFE_Brochure.pdf

98 Daivd Frankel, "Sizing the potential of behavioral energy - efficiency initiatives in the US residential market," McKinsey & Company, 2013.

99 S. Jim Scheer, "Unlocking the Energy Efficiency Opportunity," Sustainable Energy Authority of Ireland, 2015.

100 "Changing energy behaviour -what works?" Sustainable Energy Authority of Ireland, Ireland.

101 Sneha Sachar, "Behavioural Energy Efficiency Potential for India," Alliance for an Energy Efficient Economy (AEEE). 2019.

102 Mckinsey (n 55)

103 "Bureau of Energy Efficiency," [Online]. Available: https://beeindia.gov.in/sites/default/files/publications/files/Impact%20Assessment%20202122_%20FINAL%20Report_June%202023.pdf. [Accessed October 2024].

104 Tanmay Tathagat, "Unravelling Urban Household Energy Use Patterns in India," CLASP, Washington, DC, 2020.

105 "Power Ledger", [Online]. Available: https://powerledger.io/clients/t77-bcpg-and-mea-thailand-thailand/

106 "Power Ledger", [Online]. Available: https://powerledger.io/clients/uttar-pradesh-government-india/#tnt7

107 "G20 New Delhi Leaders' Declaration," Ministry of External Affairs, Government of India, New Delhi, 2023.

108 "Bureau of Energy Efficiency," [Online]. Available: https://beeindia.gov.in/en/energy-conservation-building-code ecbc#:~:text=25%25%20savings%2C%20ECBC%2B%20building%20approx,as%20compared%20to%20conventional%20building.. [Accessed October 2024].

109 "Model Building Bye-laws," Ministry of Urban Development, Government of India, New Delhi, 2016.

110 " Bureau of Indian Standards,," 2016. [Online]. Available: https://www.bis.gov.in/standards/technical-department/national-building-code/#:~:text=The%20National%20Building%20Code%20of,Code%20for%20adoption%20by%20all. [Accessed October 2024].

Suggested citation: Godrej Design Lab, 2024. Building a Climate Conscious India: Scalable solutions for a low-carbon built environment.

Research Team and Authors:
Authors: Himanshu Dixit, Council on Energy, Environment and Water (CEEW); Raj Kumar Balasubramaniyan, Integrative Design Solutions (IDS), Kanagaraj Ganesan, IDS; Karthik Ganesan, CEEW; Manna Elizabeth Sam, IDS; Sonal Kumar, CEEW

Design, Layout and Illustration: Revisual Labs (Divya Ribeiro, Kaashvi Kothari, Tulika Patel, Aabha Joshi, Ruby Rybin, Shivani Singh, Aman Bhargava and Gurman Bhatia)
https://revisual.co/

GODREJ DESIGN LAB

Godrej Design Lab is an initiative of Godrej Enterprise Group to encourage and advance design excellence and exploration. It is our way to reach out and collaborate on multiple fronts with the ever growing Indian design ecosystem. Since 2014, we have worked with talented individuals, firms, and organizations to explore how design can innovate and impact, making pioneering strides in the areas of product and architectural design, material development and social impact.

https://designlab.godrejenterprises.com/

CEEW THE COUNCIL

The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. The Council addresses pressing global challenges through an integrated and internationally focused approach. CEEW has a footprint in over 20 Indian states and has repeatedly featured among the world's best managed and independent think tanks.

https://www.ceew.in/

Integrative Design Solutions

Integrative Design Solutions (IDS), founded in 2015, is dedicated to driving sustainable transformation in the built environment. IDS delivers innovative solutions in building energy efficiency, sustainable cooling, and climate-neutral cities, addressing environmental, social, and economic challenges. Through policy advocacy, applied research, and technical consulting services, IDS collaborates with governments, organizations, and institutions to develop and implement impactful solutions locally and globally.

https://ids-pl.com/

Building a Climate Conscious India
CONSCIOUS TRENDS REPORT 2024