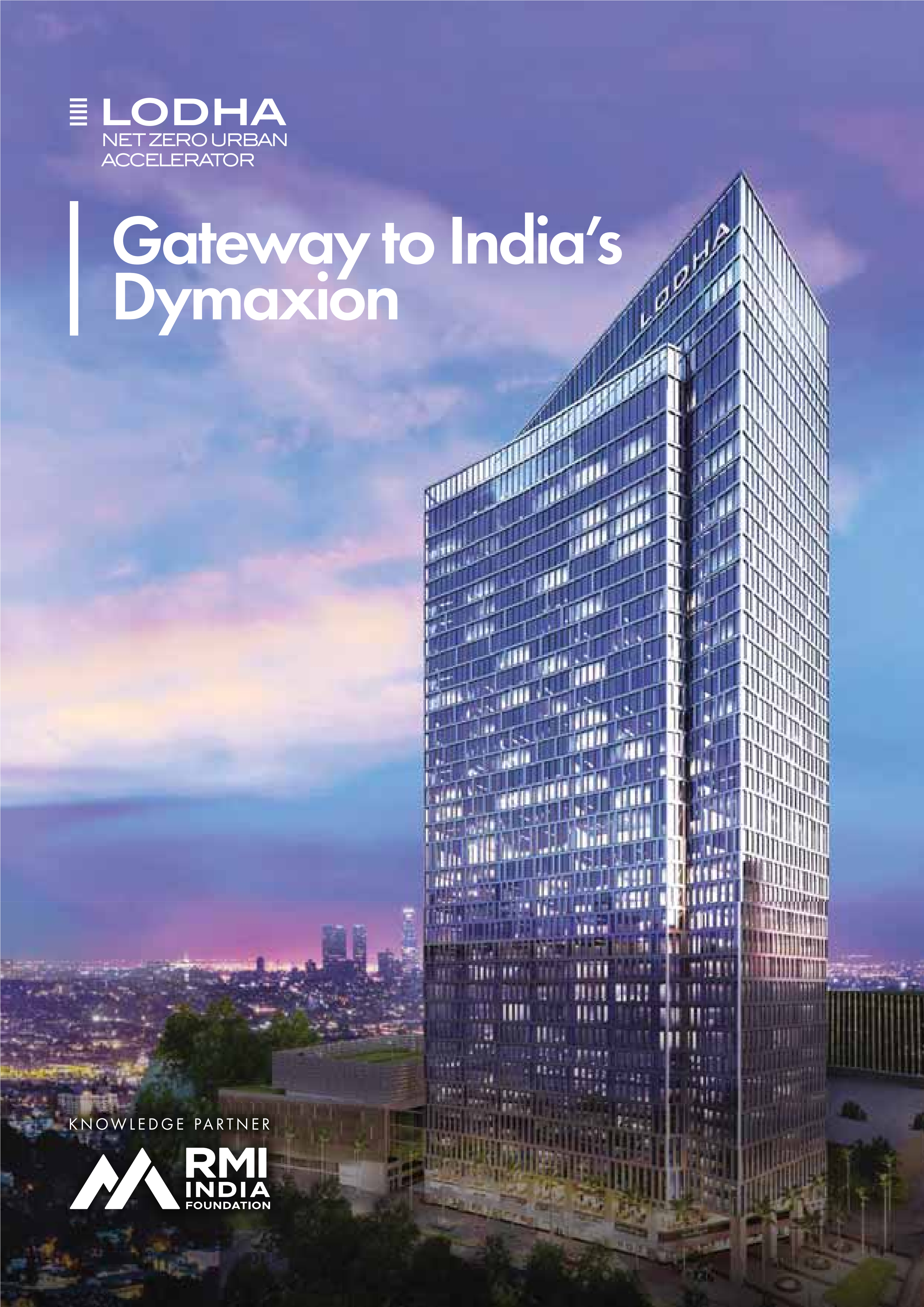
LODHA
NET ZERO URBAN ACCELERATOR

Gateway to India's Dymaxion



KNOWLEDGE PARTNER

RMI INDIA FOUNDATION

Maximum gain of advantage from minimal energy input

Transforming the built environment is critical to achieving India's ambitious net-zero climate targets announced by the Hon'ble Prime Minister at COP26. Gateway to India's Dymaxion is a publication indicative of India's cultural prowess represented in its buildings and its embrace of a commitment towards a sustainable future. Together, this document encapsulates the spirit of innovative, collaborative, efficient, futuristic, and sustainable growth that India aspires to in its built environments. With India's building stock set to double in the next two decades, the sector has significant responsibility and opportunity to reduce greenhouse gas emissions. Recognising the sector's pivotal role, Lodha and RMI India Foundation established the Net-Zero Urban Accelerator in July 2022. This initiative is not merely a response to the climate challenge, it's a vision to redefine urban development and lead India's transition towards net-zero by 2070.

The Accelerator focuses on enhancing resilience, health, affordability and access to energy services for all by developing actionable initiatives under five focus areas: Embodied Carbon, Passive and Active Thermal Comfort Solutions, Equipment Efficiency, Clean Energy and Clean Mobility. The flagship Palava City project by Lodha serves as a unique living laboratory for the Accelerator that can host as well as promote experiments and innovations by thermal comfort to build integrative sustainable solutions at the city scale. It will also be a resource hub and a go-to platform for industry and policymakers charting India's decarbonisation journey.

Why the built environment?

Buildings and infrastructure leave an imprint on the planet that could last for decades, which is why smart and sustainable buildings are key to ensure a better life for us, and for generations to come. However, the unlikelihood of restricting global warming to 1.5°C is a stark reminder of the immense challenge we face. The IPCC report indicates that, to stay within the 1.5°C limit, global greenhouse gas (GHG) emissions need to be reduced by at least 43% by 2030, compared to 2019 levels, and by at least 60% by 2035. This decade is crucial for achieving these targets.

The built environment generates over 40% of annual global CO_2 emissions.

Of those total emissions, building operations are responsible for 27% annually, while building and infrastructure materials and construction (typically referred to as embodied carbon) are responsible for an additional 13% annually.

Built Environment Global CO_2 Emissions

28%
Building Operations

6%
Buildings Construction - Concrete, Aluminium and Steel

9%
Other building materials and construction industry

34%
Final Energy Demand

Lodha Net Zero Urban Accelerator

With a vision of 'Building a Better Life', Lodha is committed to reducing emissions significantly to ensure we leave a net positive impact on the environment. To achieve this goal, in partnership with RMI India Foundation, we launched the Lodha Net Zero Urban Accelerator in July 2022. It is a pioneering initiative with a goal to make net-zero the new normal for the built environment, thereby accelerating and maximising the building sector's contribution to India's 2070 net-zero emissions target.

95%
Lodha's operational energy consumption transitioned to RE

35%
More efficient: Average operational EPI of 41kWh/m^2/year recorded

10M
Kilometres of shared mobility enabled

1.5–2°C

Cooler than neighbouring areas: Accelerator's Living Lab—Palava City

25%

Reduction in embodied carbon emissions from greener concrete mixes

4X

Super-efficient fan adoption, compared to India's average of SE fan penetration

2M+

Kilometres enabled with EV charging

.2M

Bicycle rides enabled

LODHA
NET ZERO URBAN ACCELERATOR

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Net Zero Urban Accelerator Yearbook

YEAR 1: PATHWAYS TO PROGRESS

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ABOUT LODHA

At Lodha, we are redefining the way people live and work. Driven by our vision of Building a Better Life, we view real estate as more than physical spaces — it's about enriching lives through nurturing and enabling environments. Our developments deliver the highest level of design and craftsmanship, uncompromising quality, world-class amenities, and unparalleled service — putting them in the league of the world's finest. We are India's No.1 real estate developer* with presence residential, retail, commercial and logistics and warehousing. We have delivered an area of ~9.4 crore sq.ft.** and have 33 on-going projects and 12 planned projects.^ We are committed to leaving a net positive impact on the environment as well as the communities we touch. With our ambitious net-zero targets across scope 1, 2 and 3, we are leading the way for India's net-zero transition by 2070.

*By residential sales since FY14

**Area developed till March 2023

^As on 31st March 2023

ABOUT RMI INDIA FOUNDATION

RMI Energy Solutions India Foundation ("RMI India Foundation")'s mission is to support the transformation of India's economy into a clean, thriving, and inclusive energy future. This mission is in line with the country's bold ambition to achieve a net-zero emissions economy by 2070. We aim to drive impact on the ground through deep research and rigorous analysis, which informs the development of sustainable clean energy policies and programmes across the country to enhance the lives and livelihoods of all Indians.

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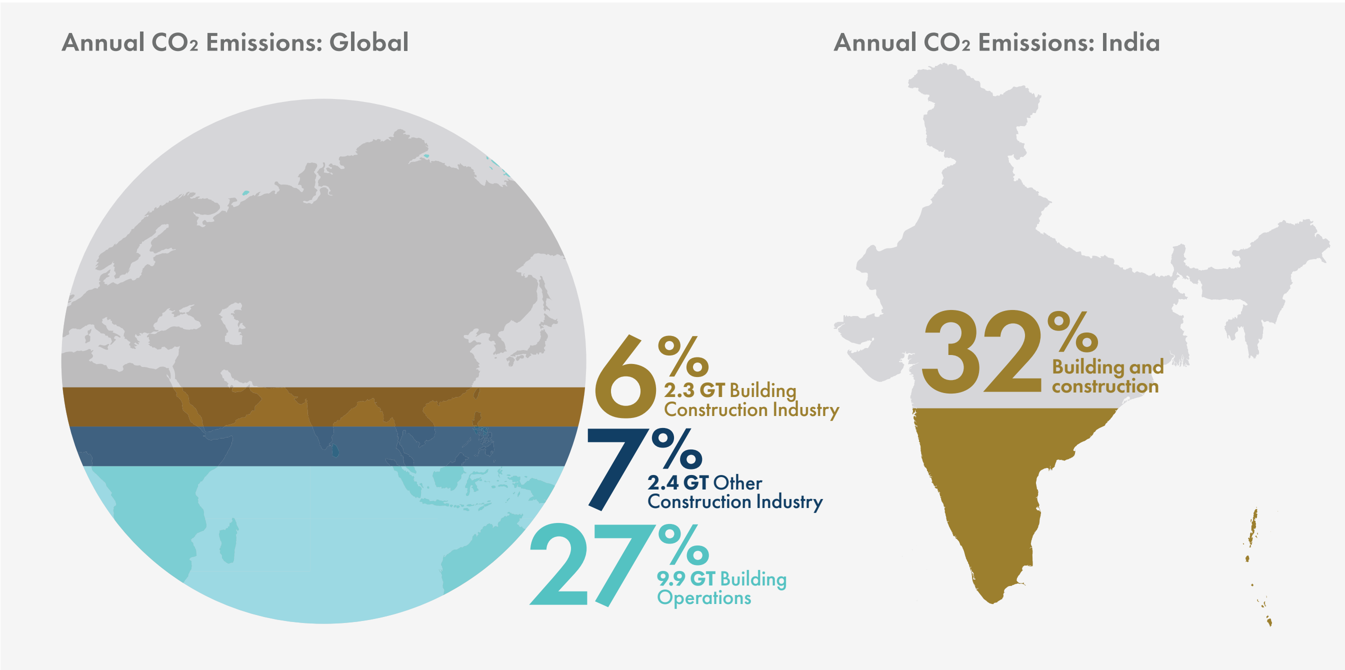
Executive Summary

Rising global greenhouse gas (GHG) emissions has led to worsening the impact of global warming. These emissions expose us to severe weather anomalies and potentially harmful consequences for both the economy and society. Notably, over 40% of the world's GHG emissions originate from the built environment.

Building operations constitute roughly one-third of India's total energy consumption. Additionally, around 10% of the nation's energy is dedicated to manufacturing building materials and constructing new edifices. Without implementation of policies, market penetration of embodied carbon materials, energy efficient appliances and technlogical disruption, projections suggest that the buildings sector's energy consumption could surpass the current usage by three times by 2050, leading to an almost quadrupled increase in carbon emissions.

EXHIBIT ES1 **WHY BUILT ENVIRONMENT?**



An integrated or whole-system approach that emphasises embodied carbon, operational carbon, clean mobility and clean energy has the potential to slash carbon emissions from buildings by a significant 600 million tonnes by 2030, as per an NIUA report. The report also suggests that the buildings sector can reduce carbon emissions intensity by 45% by 2030 compared with that in 2005, in line with the NDC. Such substantial possibilities present a favourable opportunity to initiate sector decarbonisation in close collaboration with prominent developers and government entities.

As the largest real estate developer in India, Lodha possesses a distinct capability to conceive extensive city-scale projects that comprehensively integrate all aspects of the built environment in a sustainable fashion and represent a market-shaping scale. Recognising the immense opportunity to reduce carbon emissions by utilising low-embodied-carbon materials, passive design strategies, highly efficient cooling interventions and widespread adoption of electric vehicles (EVs) and renewable energy (RE) within the built environment, Lodha, in collaboration with RMI India Foundation as its knowledge partner, established the Net Zero Urban Accelerator in July 2022.

The Lodha Net Zero Urban Accelerator is a pioneering initiative with a goal to make net-zero the new normal for the built environment, thereby accelerating and maximising the building sector's contribution to India's 2070 net-zero emissions target. The Accelerator focuses on enhancing resilience, health, affordability and access to energy services for all by developing actionable initiatives in five key areas: embodied carbon, passive design solutions, efficient equipment, clean energy and clean mobility. Palava — Lodha's flagship city development — is India's first integrated greenfield smart city and a template for sustainable urbanisation. The Accelerator will leverage this unique opportunity, with Palava serving as a unique living laboratory and lighthouse example.

The Accelerator brings together industry, experts, policymakers, academia and occupants to build integrative sustainable solutions at the city scale and serves as a resource hub and go-to platform for charting India's decarbonisation journey. The engagement will involve technologies, business models, financing, policies and programmes to accelerate net-zero implementation. This model can generate scalable solutions to propel India's burgeoning built environment towards zero carbon.

EXHIBIT ES2 **ACTION LEVERS OF THE ACCELERATOR**

NET-ZERO ACCELERATOR

WHAT IS IT?

Collaborations of rare reach, range and expertise:

- LODHA
- RMI INDIA FOUNDATION

Plus other sector stakeholders:

- Supply Chain and Solution Providers
- Finance and Investors
- Building End-users
- Policy-makers
- DISCOMs

HOW DOES IT WORK?

Craft and deliver innovative initiatives towards India's net-zero commitment, using facilitated multi-stakeholder engagement, integrative design, and research & development.

ACTION AREAS	OUTCOMES
INTEGRATE	Create whole-system roadmaps and tactical playbooks for portfolio decarbonisation.
DEMONSTRATE	Pilot and assess interventions with high potential to reduce energy and carbon, emphasising whole-systems value.
COLLABORATE	Engage stakeholders around business models, financing or policies/ programmes to accelerate net-zero implementation.
AGGREGATE	Jumpstart market for emerging high-performance equipment and services, achieve critical scale in pilot programmes.
PROPAGATE	Drive a proliferation of net-zero across the industry and policy ecosystem.

WHAT DOES IT ACHIEVE?

INCREASE

RESILIENCE — HEALTH — COOLING ACCESS — AFFORDABILITY

DECREASE

CARBON — ENERGY COSTS — RISKS — INFRASTRUCTURE COSTS

1

INTEGRATE

Create a whole-system roadmap to achieve net-zero emissions, calibrated within Lodha's portfolio across Scopes 1, 2, 3, and 4.

2

DEMONSTRATE

Pilot and assess tactical interventions with high potential to reduce energy consumption and carbon emissions in new developments. Tactics may be across various scales — city, neighbourhood, building, household and equipment.

3

COLLABORATE

Engage stakeholders to identify new business models, financing innovations or targeted policies/programmes to accelerate net-zero implementation with replicability and scalability potential across India's built environment.

4 AGGREGATE

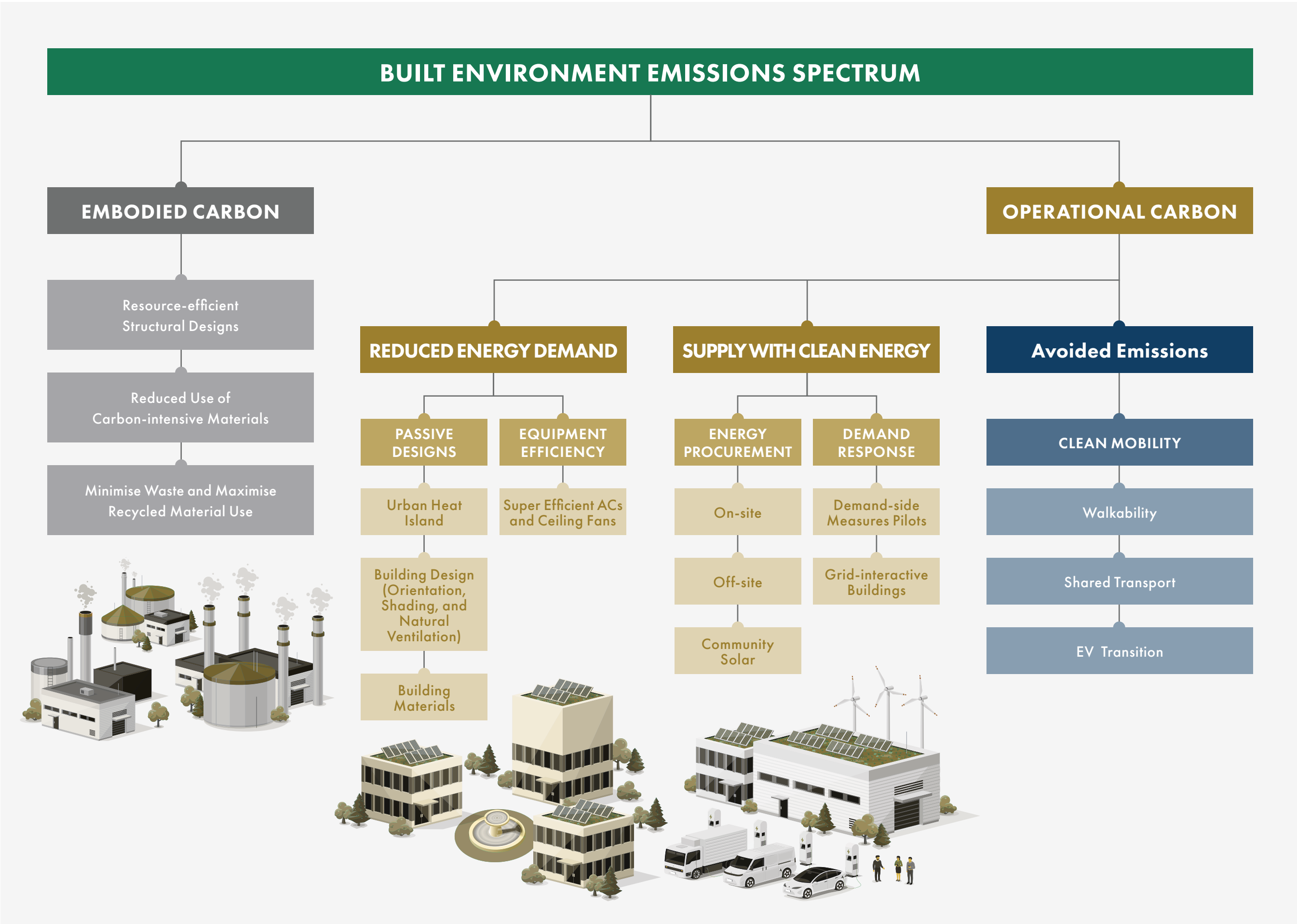
Energise markets by organising bulk demand for leading-edge equipment, materials or services, improving availability and de-risking new products for all major stakeholders.

5 PROPAGATE

Drive the proliferation of net-zero commitments by industry players and policymakers across India's built environment sector.

The Accelerator's overall vision is to create and sustain a market for thermally comfortable net-zero-carbon built environment in India. The Accelerator focuses on the entire emissions spectrum of the built environment, as shown in the exhibit on the previous page.

EXHIBIT ES3 **BUILDING EMISSIONS SPECTRUM**



The Accelerator is aimed at normalising net-zero for new developments by 2030 by evolving the way we design, construct and operate buildings. The following exhibit includes a broad range of integrated solutions to minimise embodied carbon through cost-effective low-embodied-carbon design decisions and material selection, reduce energy demand through passive measures and super-efficient equipment, serve the reduced energy demand efficiently through demand flexibility and clean energy and balance any residual emissions with equivalent reduction through carbon capture and offsets.

EXHIBIT ES4 **ANNUAL GHG EMISSIONS REDUCTION OPPORTUNITIES**

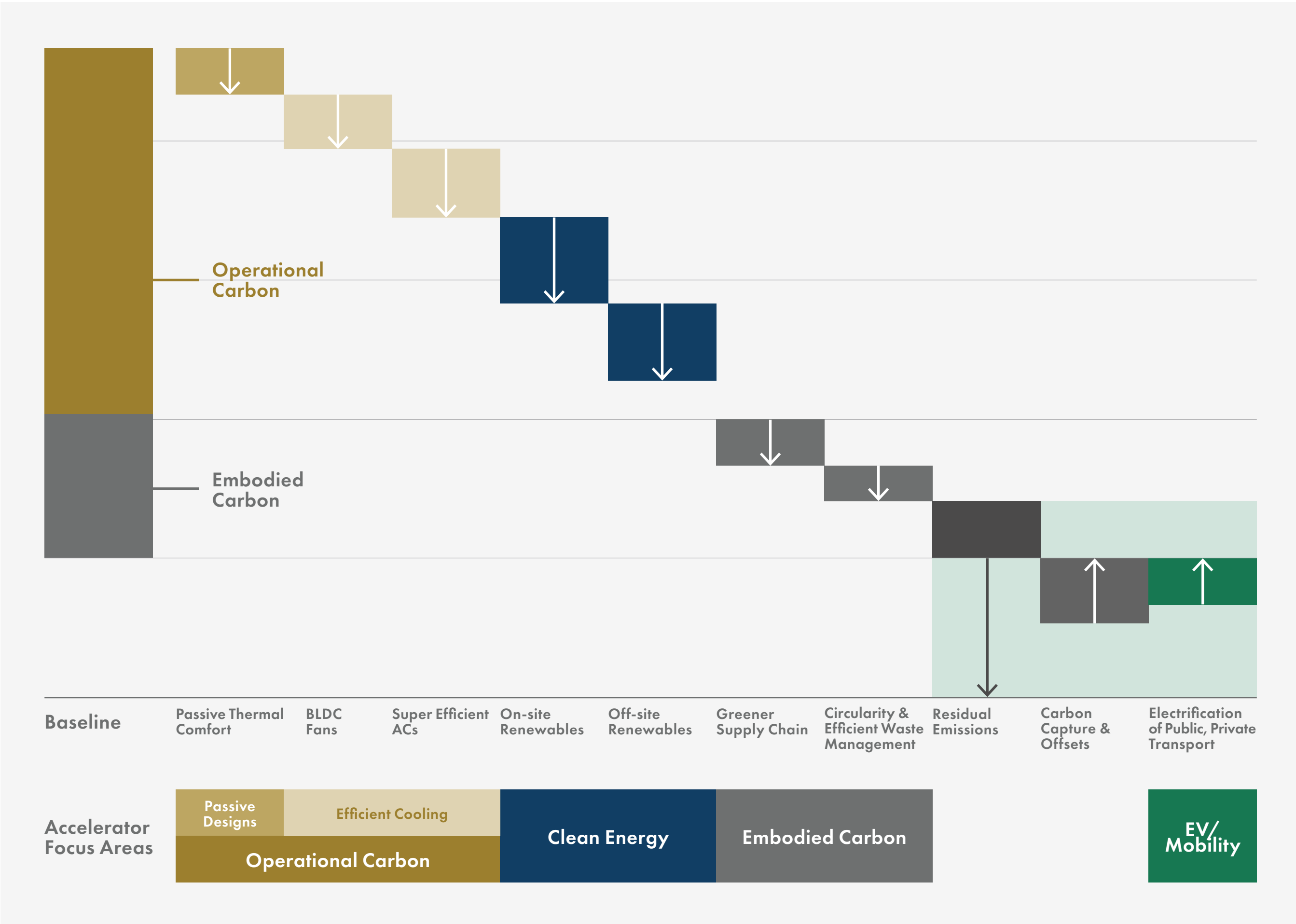


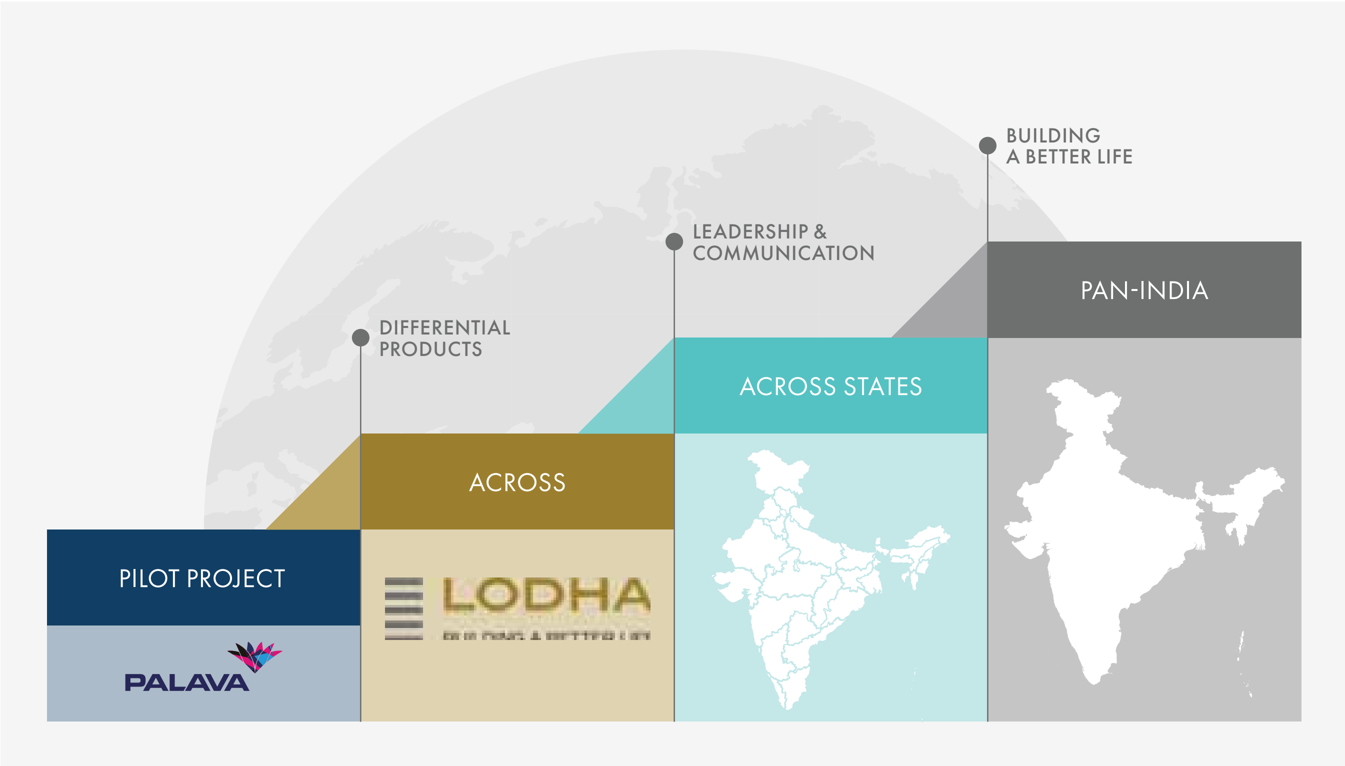
*Image not to scale; for representational purposes only

The efforts of Palava's 'living lab' will be expanded by creating specialised products, solutions and strategies targeting the designated focus domains. These distinctive programmes will be extended to other Lodha projects and the insights gained will reshape the market at the regional and national levels. This will lead the wider ecosystem to join forces and commit to the required change, supported by awareness initiatives, training and capacity-building programmes.

SCALING SOLUTIONS

For scaling, it is important to transform the supply chain of materials and technologies. A supply chain is only as strong as its weakest link, and it is critical to create a cascade of sustainable practices that flows smoothly throughout the supply chain.

EXHIBIT ES5 **SCALING VISION AND ROADMAP**



SUPPLY CHAIN TRANSFORMATION

Until entities at the foundational level of the hierarchy begin producing sustainable and climate-conscious products/components, the shift to low-carbon development will remain unrealised. This transformation requires measures at both the supply and demand sides.

Supply-side

- Industry players and manufacturers need to invest in R&D and scale the provisioning of energy-efficient, climate-resilient and low-carbon alternatives.

- This pivot requires training and capacity enhancement, incentives and promotion of peer-to-peer and field learning initiatives.

Demand-side

- Developers need to incorporate sustainable practices such as designing energy-efficient and climate-resilient buildings.

- Energy-efficient and low embodied carbon products must be procured to drive the demand for sustainable alternatives and transform the built environment.

- It is essential to collaborate with innovators to co-create/improve low-carbon alternatives by offering a platform for iterative adjustments and product/solution adaptation to real-world conditions and deploy economies of scale to tunnel through the initial cost barrier.

In addition to suppliers and procurers, industry associations possess a distinctive influence over primary and secondary procurers and suppliers. Given that their members often hold significant industry roles, they will play a pivotal part in the decarbonisation of the built environment.

Thus, aligned with the vision to accelerate the decarbonisation of the built environment, the Accelerator worked in the identified thematic areas. The updates from the first year are summarised for each thematic in the subsequent section.

EMBODIED CARBON

Within the four walls of our buildings is an often overlooked source of carbon emissions, commonly referred to as embodied carbon (EC) — the millions of tons of indirect emissions associated with extracting, manufacturing, and construction use of materials and products over the life cycle of a building.

- India's buildings sector emits nearly 500 million metric tons of carbon dioxide (CO_2e) in embodied carbon annually.

- Urbanisation, combined with the overall growth in India's population, is projected to add 416 million people to urban areas by 2050, nearly doubling the size of India's building stock in the next two decades.

- The surge is linked to around 250 ancillary industries associated with the real estate industry and could escalate the associated embodied carbon emissions drastically.

To navigate this pivotal convergence of urbanisation and emissions growth, it is essential to balance development with environmental stewardship by establishing pathways to decarbonise building design, construction and material supply chains.

Lodha actively pursues a whole-system approach to reduce EC in its building developments by outlining an array of strategies spanning design, procurement and construction.

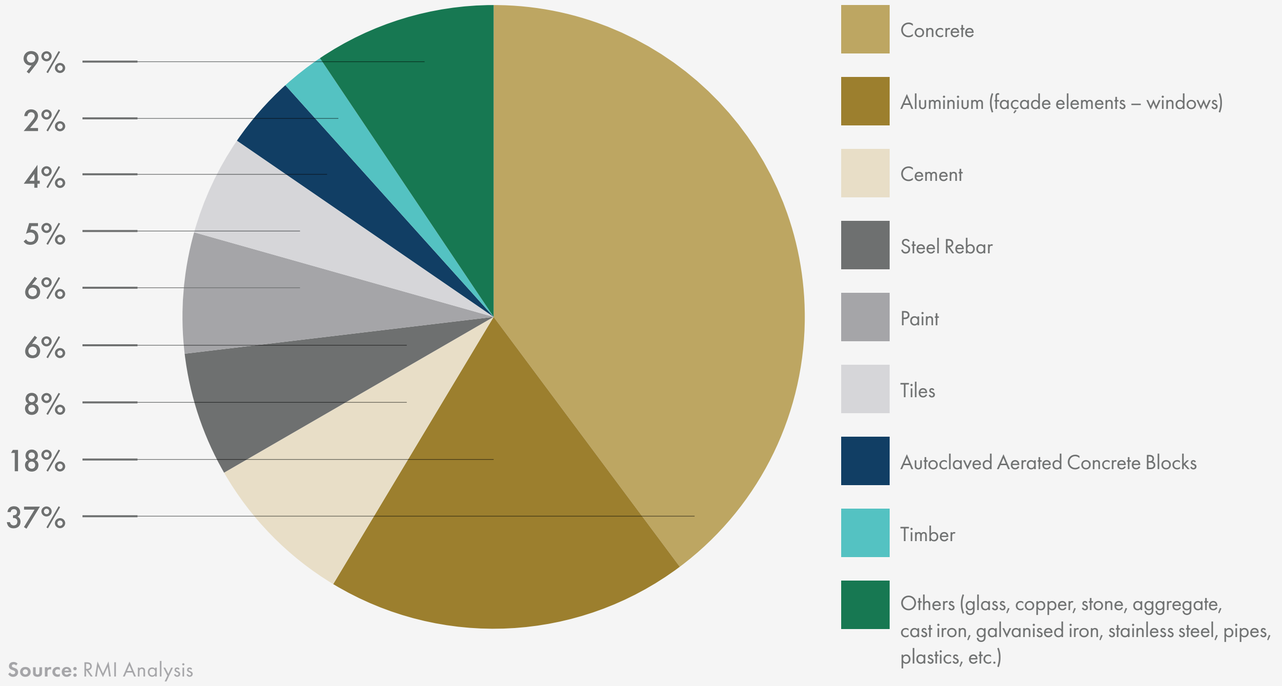
- Establishing a baseline of EC in building construction is an essential first step in measuring the success of EC reduction strategies.

- The Accelerator has conducted a comprehensive baselining study including the major material categories used in a typical multifamily building. It provides valuable data to identify high-impact opportunities to reduce the EC footprint of Lodha's portfolio by 5% and specifically concrete by 10% year-on-year contingent on the accomplishments and strategies of its supply chain partners.

- The analysis indicates an EC footprint of 387 $kgCO_2e/m^2$, as depicted in Exhibit ES4, which is notably modest compared with global benchmarks, and indicates that cement, concrete and steel rebar contribute up to 50% of the EC emissions, establishing them as a key focus area for carbon reduction.

Lodha systematically explores the usage of low-carbon concrete mixes and alternate cementitious materials such as LC3 by critically assessing the buildability and cost implications through pilots. Subsequently, strategies will be developed to reduce the EC footprint of steel, glass, aluminium and other building materials.

EXHIBIT ES6 **EC MATERIAL FOOTPRINT CONCRETE STRUCTURE (APPROX. 387 KG CO_2e/m^2)**



Source: RMI Analysis

Stakeholder consultations with material suppliers

To better understand the challenges and opportunities related to producing and adopting low-carbon products in the construction industry, the Accelerator team conducted stakeholder consultations with several cement and concrete manufacturers. To sum up the discussions with supply chain partners, barriers to the production and adoption of low-carbon products include emissions-related data scarcity, perceived uncertainty around field performance, limited policy push and demand-side market signals, low awareness of market-ready low-EC products, supply-chain challenges and evolving regulatory and green building certification targets concerning EC.

Action pathways — Embodied Carbon

Given the cost, risk and durability of alternative low-embodied carbon infrastructure, stakeholders are understandably cautious about adopting new practices. The Accelerator aims for the following:

- Bridge the information gap by conducting similar benchmarking analysis, incorporating third-party verification for other common typologies (such as composite, precast and industrial warehouses) and identifying the highest-impact materials for lowering EC.

- Systematically explore the usage of low-carbon concrete mixes and alternate cementitious materials such as LC3 among others by critically assessing the buildability and cost implications through pilots. Subsequently, strategies will be developed to reduce the EC footprint of steel, glass, aluminium and other building materials.

- Facilitate the generation of evidence, foster cross-border partnerships and signal tangible demand to accelerate the production and adoption of low-carbon building materials in India.

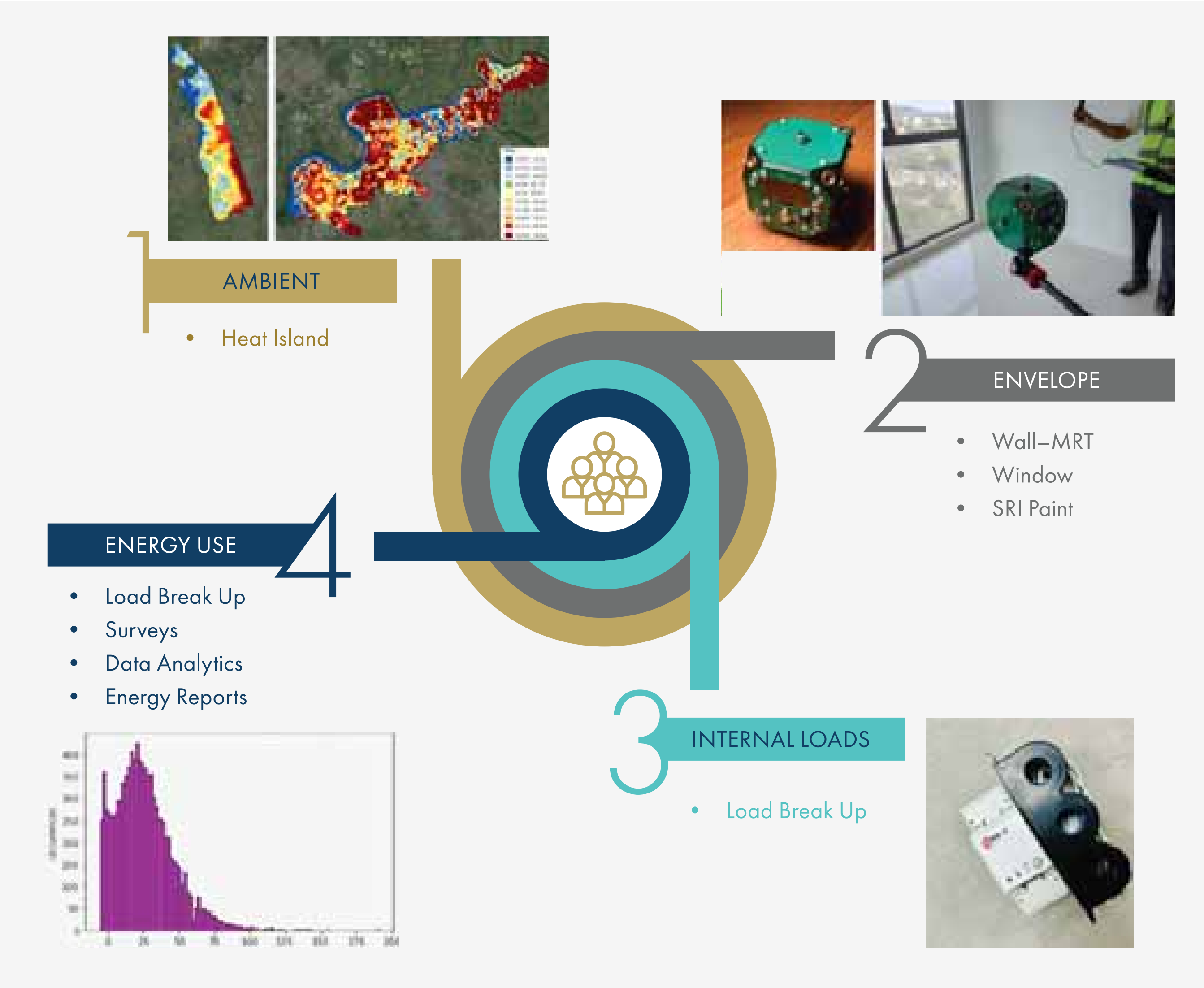
REDUCED ENERGY AND COOLING REQUIREMENT TO ACHIEVE THERMAL COMFORT

The dilemma of escalating global temperatures is evidenced by the fact that the 10 hottest years in recorded history have all been after 2010. In 2022, the surface temperature surpassed the 20th-century average of 57.0°F (13.9°C) by 1.55°F (0.86°C). Addressing the repercussions of mounting temperatures will necessitate significant endeavours and energy investments to ensure the thermal comfort of billions of individuals in urban areas and residences.

As the world's most populous nation, India is grappling with swift urbanisation intertwined with heightened economic affluence. This confluence is on the brink of triggering a notable upswing in energy requisites, prominently stemming from the constructed landscape, with cooling and thermal comfort demands constituting a significant portion.

These initiatives are aimed at providing thermal comfort to millions of people by benchmarking residential energy profile based on field measurements and prioritising performance improvement measures across energy-impacting layers, namely, ambient, envelope, internal loads and user behavior, as shown in Exhibit ES7.

EXHIBIT ES7 **ACCELERATOR'S WORK TO REDUCE ENERGY CONSUMPTION AT PALAVA**



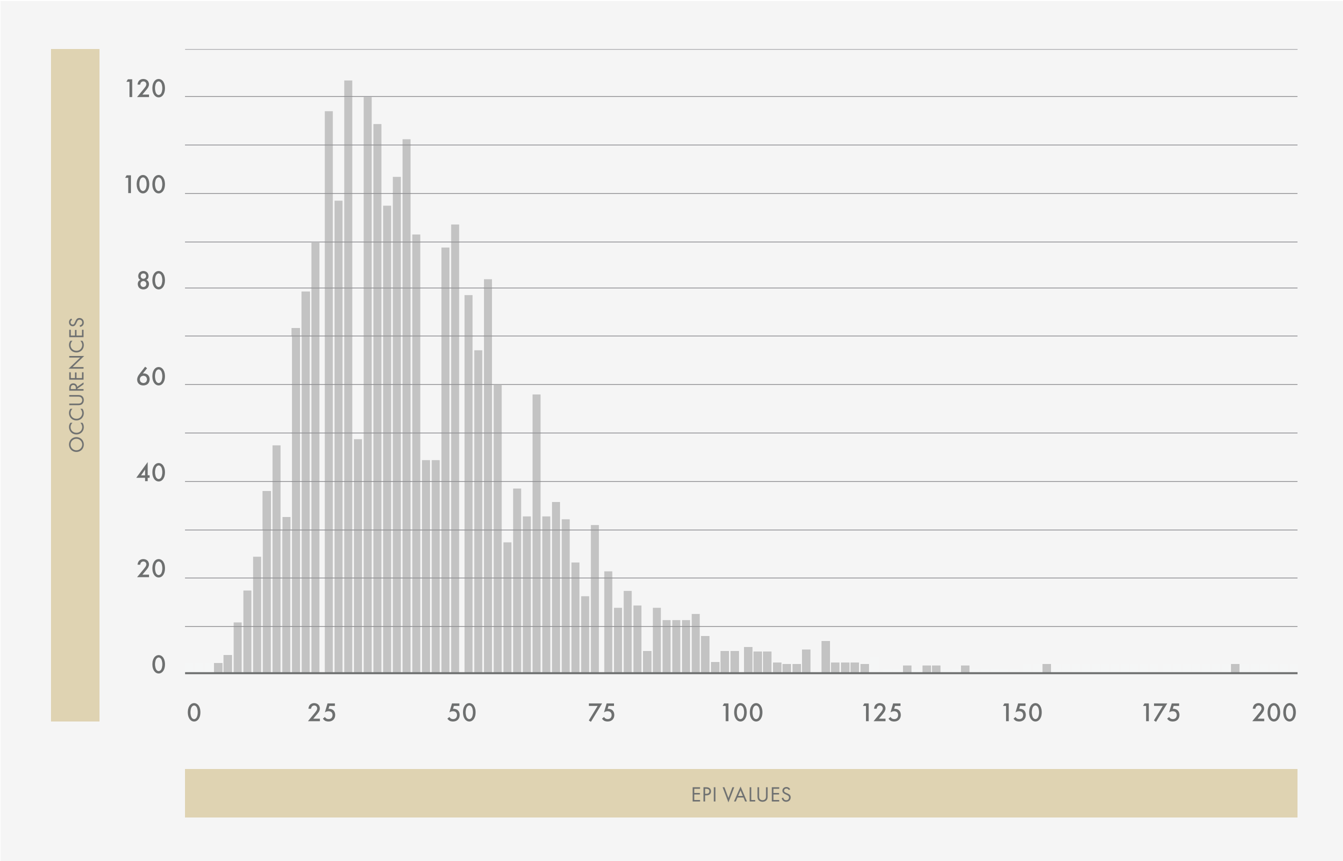
Energy use intensity

Energy use was analysed based on energy consumption data of around 10,000 households in Palava.

- The median EPI value was found to be 41Kwh/sm/year, which is 35% lesser energy than the industry benchmark for residential buildings in hot and humid climates, which may partly indicate energy-efficient design and equipment.

- Palava has 100% penetration of room air-conditioners (RACs) and reflects new construction patterns and expectations of access to cooling, contrasting the average household RAC penetration of under 10% in Indian population.

EXHIBIT ES8 **MEDIAN EPI OF HOMES IN PALAVA**



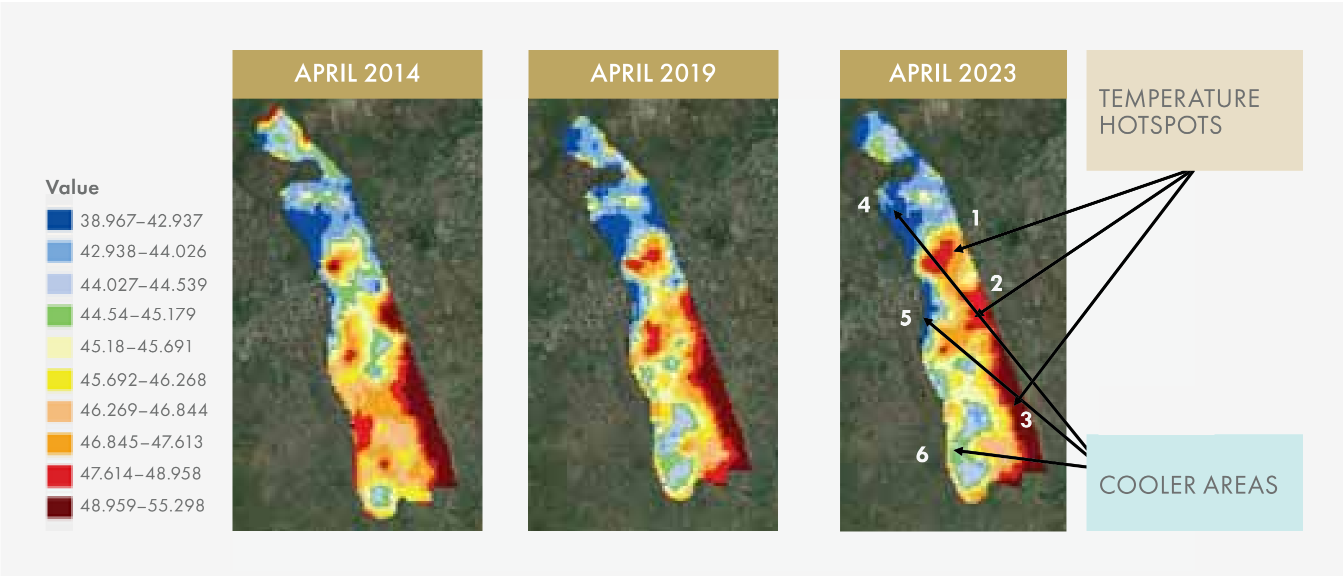
In the coming year, the Accelerator will focus on collecting more baseline data through surveys and behaviour studies and energy data disaggregation measurements. This data will be used to evaluate and propose physical and behavioural energy efficiency interventions. The Accelerator will subsequently inform policy discourse for driving actions on building and equipment performance.

URBAN HEAT ASSESSMENT

The Accelerator mapped the hotspots in a sector in Palava and assessed the historic data available from land surface temperature (LST) images. Initial findings suggest that Palava has cooled much faster than its neighbouring areas and a downward trend is expected in the future. Currently, Palava is around 1.5 – 2°C cooler than its neighbouring areas. This can be attributed to urban cooling strategies such as green cover and reflective roofs adopted in Palava.

The study will be further substantiated using on-site measurements and validating the urban cooling strategies implemented in Palava. The study results will inform future adaptation strategies such as enhanced cool roofs, smart surfaces and nature-based solutions to bring down the rising temperature within the communities and reduce cooling demand.

EXHIBIT ES9 **LAND SATELLITE TEMPERATURE OF PALAVA PHASE 1**



Source: Landsat 7 and 8 imagery

PASSIVE SOLUTIONS AND NEXT-GENERATION COOLING TECHNOLOGIES

The Accelerator raises awareness about the advantages of both passive and active cooling systems, validates the efficacy of next-generation cooling solutions and fosters a market for these technologies.

In the current year of the Accelerator, experiments are being conducted using passive cooling techniques, and the real world performance of next-generation cooling solutions, including 5X RACs and BLDC fans, is being assessed. These initiatives are driven by the broad aim of accumulating empirical data on the effectiveness of useful solutions, thus instilling confidence among diverse stakeholders and facilitating their broad-scale adoption.

1

Passive solutions

The Accelerator has commenced testing the performance of high performance glass. In the first round, it assessed how the utilisation of high-performance glass (U value of 2.9W/m²/°K and shading coefficient of –0.34) compares with traditional glass (U value of 5.8W/m²/°K and shading coefficient of 0.82) in influencing indoor temperatures.

Preliminary tests confirmed the ability to reduce daytime peak air temperatures in test spaces. Passive solutions such as cool roofs, additional glazing options, shading, solar chimneys, radiant cooling and ventilation, among a host of other passive solutions, will be explored in the second year of the Accelerator's journey.

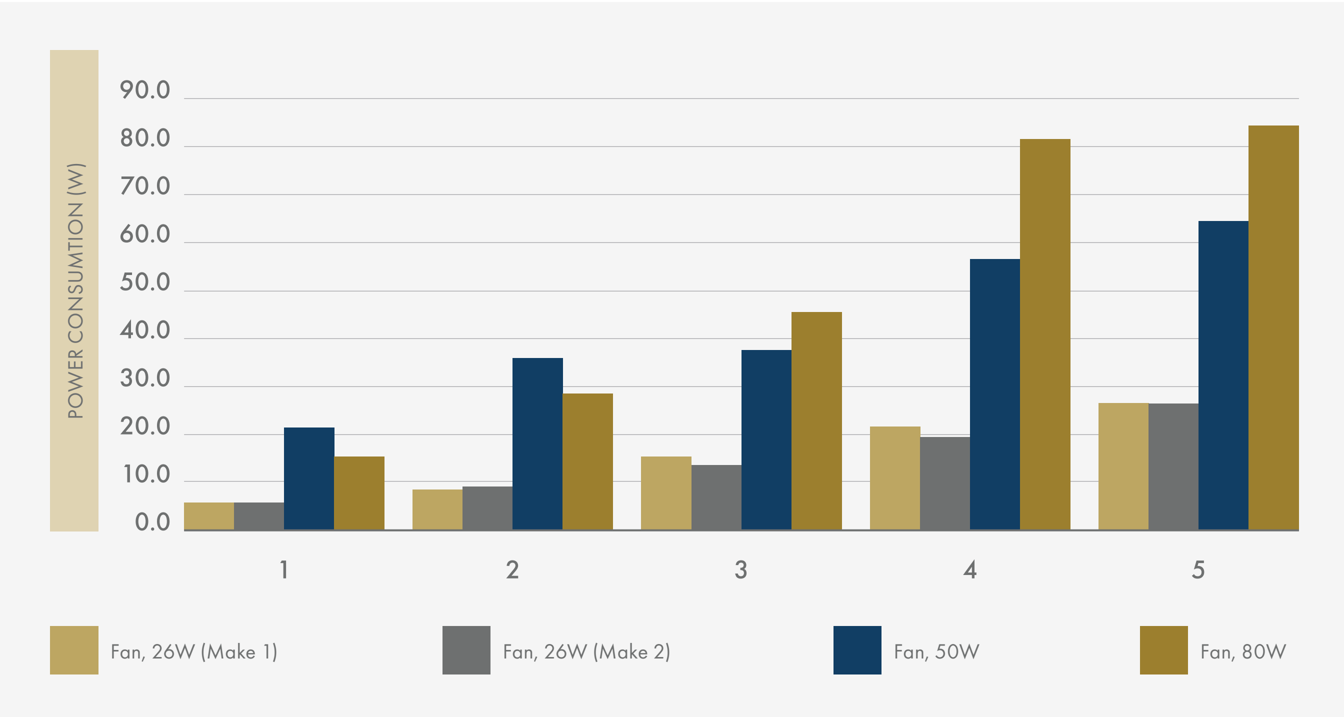
2 Super-efficient air-conditioners (ACs)

The Accelerator is currently evaluating the real-world performance of 5X reduced climate impact ACs developed as part of the global cooling prize initiative. This evaluation is anticipated to be completed in the second year of the Accelerator programme.

3 Ceiling fans

The on-ground performance of various fans of different wattages (four of each wattage), ranging from 70W fans to super-efficient 28W BLDC ceiling fans, was analysed. The Accelerator showcased and generated credible evidence of energy savings, enabling procurement decision-making for new installations and retrofits of BLDC fans in new developments and existing spaces where fans were pre-installed by Lodha.

EXHIBIT ES10 **POWER (W) AT VARIOUS FAN SPEEDS**



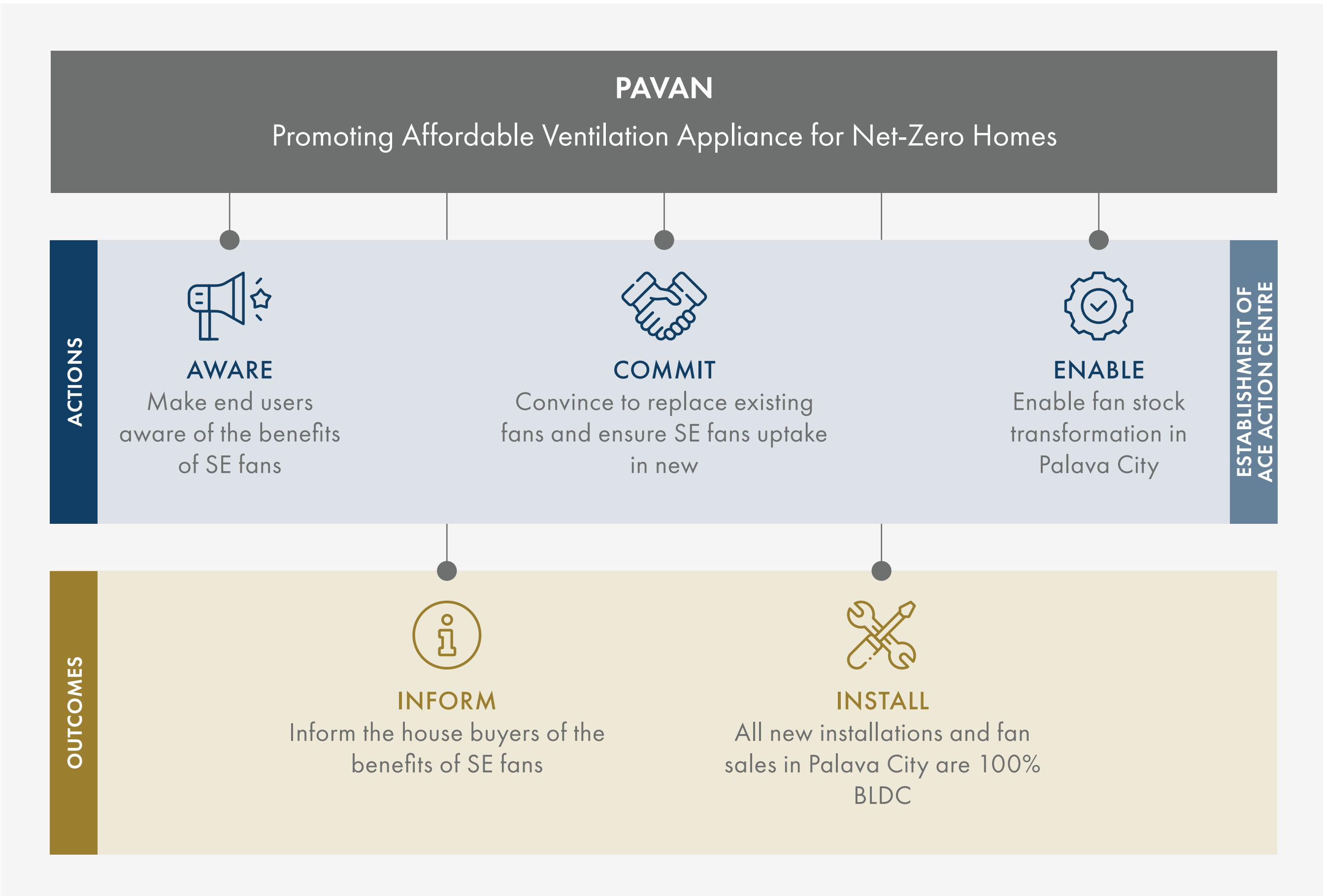
The Accelerator projects an overall energy savings potential of 13GWh annually if the expected households within Palava coming up in the next 10 years opt for BLDC fans instead of conventional fans.

Action Pathways - Reduced energy consumption and thermal comfort

Awareness: To swiftly address cooling challenges, the Accelerator proposes **Mission PAVAN** (Promoting Affordable Ventilation Appliance for Net-Zero Homes). The on-ground **ACE (Aware, Commit, Enable)** Action Centre associated with this mission will focus on three key areas:

1. Creating awareness among residents,
2. Demonstrating commitment from various stakeholders, including but not limited to residents, manufacturers, and Lodha, and
3. Facilitating on-ground implementations and installations, pushing market transformation towards super-efficient technologies.

EXHIBIT ES11 **PAVAN – PROMOTING AFFORDABLE VENTILATION APPLIANCE FOR THE NET-ZERO HOMES**



Technology: The Accelerator is actively assessing the real-world performance of 5X reduce climate impact ACs from the Global Cooling Prize initiative, with results expected in the second year of the programme.

Market Strategies: The Accelerator envisions deploying a blend of passive strategies and super-efficient appliances, notably fans and ACs. The strategies include:

- Encouraging bulk procurement by real estate developers and government bodies,
- Leveraging preferred pricing and negotiations,
- Innovating distribution through avenues such as company kiosks and
- Showcasing the benefits of cutting-edge technologies through targeted outreach.

The goal is to curate replicable strategies that inspire wider adoption among developers and governmental bodies.

CLEAN ENERGY

India's goal of achieving 50% non-fossil-fuel-based power generation by 2030 and deploying 50GW of RE annually until 2027–28 to meet this goal is undoubtedly ambitious. Accelerating consumer adoption of RE will play a vital role in India's efforts to meet its 2030 targets.

Nearly 36% of India's existing electricity demand can be attributed to the commercial and industrial (C&I) sector. Of the C&I sector's total electricity demand, less than 10% is currently sourced from RE. This implies that there is scope to decarbonise at least 90% of C&I's electricity demand, which could add about 450GW of RE capacity. Along with C&I consumers, residential consumers, who represent 30% of the country's existing electricity demand, have a strong incentive to adopt RE. This is because RE (especially solar) is one of the most economical sources of electricity available in the country today, offering consumers the opportunity to save on electricity bills.

Multiple pathways — short-term and long-term — can be explored to procure RE. For instance, long-term procurement models include on-site (capex, third-party PPA) and off-site (open access via third-party PPA, group captive, green energy open access) deployment models. New models such as virtual power purchase agreements (VPPAs) and community solar are also emerging. Short-term power procurement models include green tariff, green term ahead market (GTAM), RE certificates (RECs) and P2P trading.

Consultations with renewable energy (RE) developers

Following the identification and clustering of the annual electricity demand across various Lodha sites (amounting to over 15 million units) at the portfolio level, India's leading RE developers were consulted to identify the least-cost RE pathways for individual sites based on the existing policy and regulatory framework in Maharashtra. These pathways include on-site solar generation and open access via third-party and group captive mechanisms. The on-site RE generation potential of Lodha's city-scale development 'Palava' was also identified.

The potential for integrating grid-interactive building elements such as battery storage and demand response is being explored at a sample captive building to further minimise electricity costs.

Action pathway — Clean Energy

- The Accelerator would focus on sharing knowledge around RE pathways for consumers across categories, leading to electricity savings.
- The Accelerator will help unlock novel RE procurement pathways such as green energy open access and community solar that can be tapped by MSME and residential consumers, respectively. This will include engaging with multiple stakeholders, including RE developers, consumers and the regulatory ecosystem. Palava has the potential to become a testbed to pilot and pioneer community solar for domestic consumers.
- The Accelerator aims to identify the potential for grid interactive building elements within the Lodha portfolio via technology assessments and pilots to optimise electricity costs and present the learnings with the wide residential, commercial and industrial consumer ecosystem.

CLEAN MOBILITY

Globally, the transport sector accounts for 23% of the total GHG emissions responsible for climate change. Therefore, decarbonisation by transitioning to a clean mobility future is the key goal of governments across the world. In India, the transport sector contributes to 14% of all scope 1 carbon dioxide (CO_2) emissions, of which nearly 90% are from road-based transport.[i] Therefore, a crucial pathway to achieving India's net-zero target by 2070 is the decarbonisation of road transport.

i Scope 1 emissions are direct emissions from sources controlled or owned by an organisation.

The three-pronged approach to decarbonise focuses on eliminating the transport need by adopting the 5-10-15 walkability principle, enabling shared transport and improving overall energy efficiency and transitioning to low- and zero-emission vehicles.

One of the approaches to achieve a clean mobility future is to transition the transport sector to EVs.

India has established ambitious electrification targets, including ensuring that 30% of the private cars, 70% of the commercial vehicles and 80% of the two- and three-wheelers sold by 2030 are EVs. To accelerate the transition to EVs, the Government of India provides incentives for EVs through policy mechanisms such as the Faster Adoption and Manufacturing of Electric and Hybrid Vehicles (FAME) phases I and II. Additionally, 26 state governments have announced EV policies with state-specific targets, additional incentives and other policy levers to create an enabling environment for EV adoption. As a result, 5.3% of all vehicles sold in 2022–23 were electric.

Charging infrastructure critical to ensure accelerated EV adoption

Globally, the lack of charging and swapping infrastructure is one of the biggest barriers to EV adoption. Therefore, charging infrastructure must be deployed in anticipation of growth in EV sales. EVs can be charged privately at home or using publicly available charging. The distribution of charger type should reflect the local context.

Built environments characterised by the availability of space to park at each residence can place high reliance on home chargers. Built environments with high-density housing (e.g., flats) and limited access to home chargers at parking spaces can rely more on public charging. Another key characteristic of the built environment is the mode of transport. As charging solutions vary by vehicle segment, the charger deployment strategy should match the mobility patterns and vehicle segments in operation by the population.

Charging infrastructure deployment in India

As of August 2023, 9,113 public charging stations were operational across India (translating to a public charger-to-EV ratio of 1:182). Among states, Maharashtra has the highest number of public charging stations (2,494), followed by Delhi (1,627). To support the deployment of charging and infrastructure in cities and on highways, the government allocated ₹1,000 crore under FAME II and notified other supportive mechanisms such as mandating 20% of the parking capacity in new buildings to be EV-ready.[ii]

While several measures were put in place to encourage the widespread deployment of accessible and affordable charging infrastructure, challenges such as technology standardisation hindering innovation; limited availability of land and grid capacity for new EV loads; high land acquisition costs; limited consumer awareness for charging point installation, maintenance and use; ambiguous regulatory requirements for developers and charge point operators; limited business model flexibility; and financial incentives to support infrastructure installation remain.

Palava township as a testbed for proof points

The vision for Palava is '***to enable a phased, timebound, sustainable and inclusive transition of all two- and four-wheelers, including legacy internal combustion vehicles, to electric in the Palava township by 2045. Palava will be a replicable model for townships in India and across the world.***'

Palava can act as an ideal testbed to develop the required proof points to overcome the challenges pertaining to deploying charging infrastructure. For this, a charging and swapping infrastructure deployment plan (hereinafter called the 'action plan') is being developed. The action plan will be a roadmap for the phased installation of charging infrastructure in Palava.

Vehicle electrification targets

To understand the charging requirements of Palava, vehicle electrification targets were established for two scenarios: business-as-usual (BAU) and aggressive. The electrification targets were assessed based on the following:

- Electrification trends in Mumbai, a city with a similar demographic to Palava.
- EV penetration in countries leading the EV transition and contextualised to India.
- Lodha's net-zero targets.

Palava-specific parameters, including projected occupancy, vehicle ownership trends and resident profiles, were also considered.

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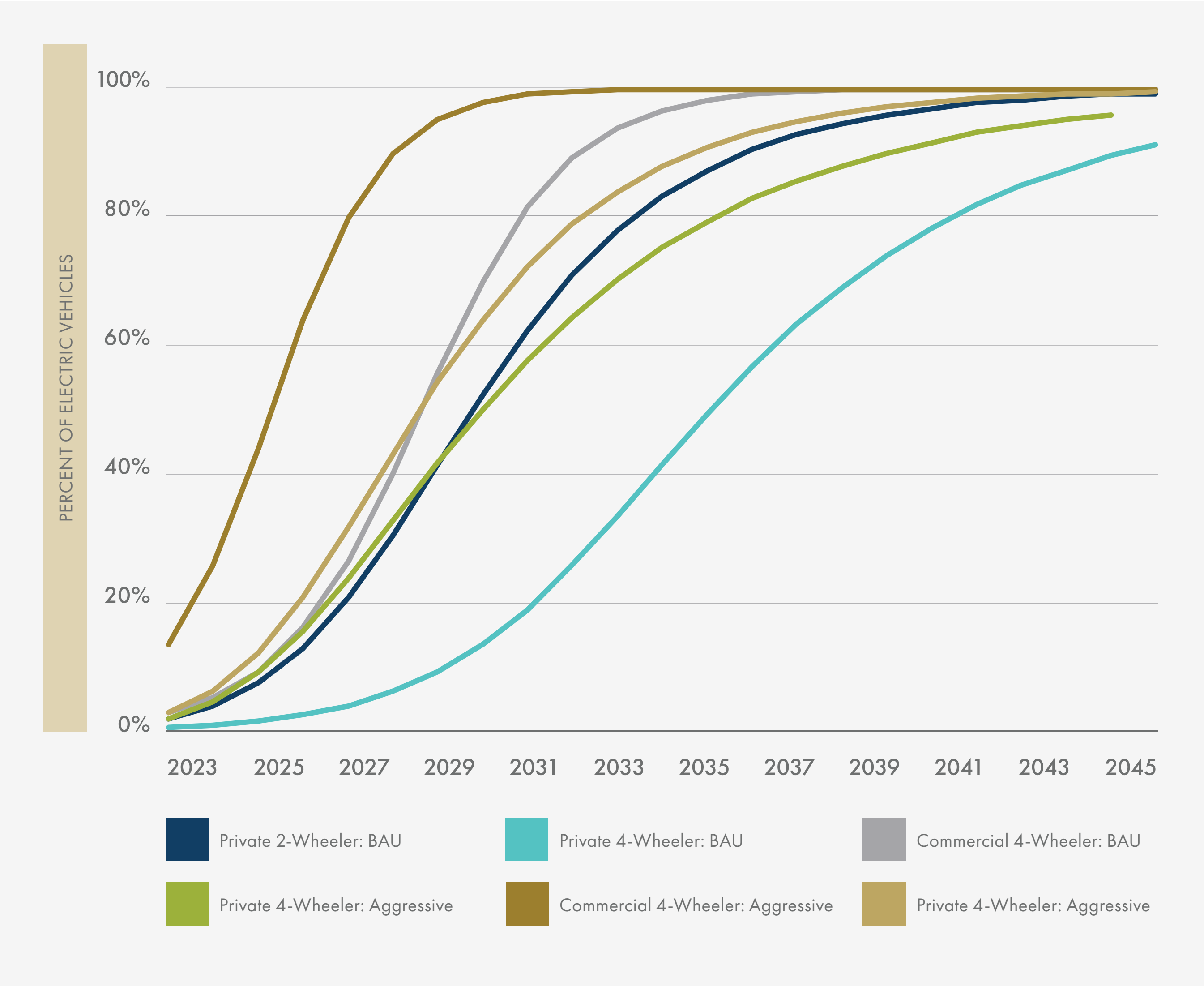
ii As per India's building bylaws (2016), charging infrastructure shall be provided on 20% of the vehicle holding capacity/ parking capacity of the premise. The building premise must have capacity for the additional power load with a safety factor of 1.25. EV-ready parking spots shall be equipped with all conduit, wiring and panel capacity, and require only the installation of the EV charger. EV-ready buildings include the installation of dedicated branch circuit(s), circuit breakers and other electrical components.

The EV penetration targets and Palava-specific parameters form the basis to assess charger requirements, including type and count. Exhibti ES12 summarises the EV penetration targets for Palava's priority segments.

EXHIBIT ES12 **ELECTRIFICATION TARGETS FOR AGGRESSIVE AND BAU SCENARIOS**



Source: RMI India Foundation

CHARGER DEPLOYMENT TARGETS

Based on the vehicle electrification goals, charger deployment targets were set to balance the charging needs of EV owners and other considerations, such as optimising energy consumption and managing costs and new load. The targets also prioritise accessible shared public chargers. Private chargers may be provided in specific instances if pre-set requirements are met. The cumulative type and number of chargers are provided in Exhibit ES12:[iii]

- By 2035, accounting for Palava's urban design and vehicle ownership patterns and mobility needs of its residents, 10 public chargers and 16 private chargers would be required for every 100 parking spaces in the aggressive scenario.

- In the aggressive electrification scenario, 57% of the public chargers would be LEV AC (3.3kW), 17% would be DC 001 (15kW) and 18% would be CCS (50kW).

- In the BAU electrification scenario, 59% of the public chargers will be LEV AC (3.3kW), 15% will be DC 001 (15kW) and 19% will be CCS (50kW).

Action pathway — Green Mobility

A key aim of deploying charging infrastructure in Palava is to develop proof points and capture lessons learned through deployment to help the ecosystem understand and overcome barriers to charging infrastructure deployment.

This process will answer the following:

- What measures must be taken to ensure regulatory compliance when installing charging stations?

- What are the commercial implications of adhering to regulatory requirements pertaining to making parking spaces in buildings EV-ready?

- How is the balance between public and home chargers to optimise costs determined? Should developers prefer one over the other?

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iii LEV: Light Electric Vehicles
AC: Alternating Current
kW: kilowatt
DC: Direct Current
CCS: Combined Charging System

To facilitate learning within the ecosystem, Lodha will report on the progress, capture and disseminate critical knowledge with all stakeholders and facilitate the development of solutions to promote scaling of charging infrastructure deployment in Palava and beyond.

THE ROAD AHEAD: NET ZERO URBAN ACCELERATOR

In essence, the Accelerator will focus on driving a systemic change for the decarbonisation of the built environment. This shift will be driven through various approaches, including the implementation of change models centred on policies, market transformation, business models and technology advancement supported by financial initiatives. To ensure a holistic transformation, it is imperative for the Accelerator to concentrate on initiatives such as consumer awareness campaigns, behaviour change initiatives, educational programmes, capacity enhancement, strategic partnerships and thought leadership. Looking ahead, the Accelerator, through its five focus areas, will address the following pivotal questions to create and sustain the market for thermally comfortable net-zero carbon homes in India.

1

Testing and innovation

How will various solutions available in India and globally be tested to establish real-world performance and generate evidence supported by data to instill confidence among various stakeholders for its adoption?

2

Policy

How can the Accelerator shape policy frameworks and foster demand and long-term viability for the selected net-zero solutions?

3

Industry supply chain

In what ways can the Accelerator revolutionise the industry's supply chain with the broad goal of encompassing all essential stakeholders within the manufacturing ecosystem of the built environment?

4

Just transition

How can the Net Zero Urban Accelerator be optimised to not only achieve its environmental goals but also generate sustainable livelihood opportunities?

The Accelerator is a forum for collecting invaluable insights from pertinent stakeholders, substantiating and fine-tuning the Accelerator's forthcoming courses of action. As part of its progression, the Accelerator aims to incorporate interaction with supply-chain leaders, policymakers, developers and solution providers, fostering their rare reach, range and expertise. The Accelerator will design, implement and scale innovative decarbonisation initiatives to jumpstart market transformation to maximise the building sector's contribution to India's 2030 NDC targets.

Of the thematic areas identified within the built environment, the Accelerator has not only work on areas illustrated below in its inaugural year but also plans to continue its focus on these and expand its activities in the future (See Exhibit below).

EXHIBIT ES13 **SNAPSHOT OF COMPLETED, ONGOING AND PLANNED ACTIVITIES OF THE ACCELERATOR**

INDIA 2030 GOALS

- Reduce the emissions intensity of its **GDP by 45% by 2030, relative to 2005 levels**
- Achieve about **50 percent cumulative electric power** installed capacity from non-fossil fuel-based energy resources by 2030
- The **buildings sector has the potential to cut carbon emissions intensity by 45% by 2030** compared with that in 2005, in line with India's NDCs.
- To support this, the Accelerator aims to demonstrate and mainstream feasible, innovative, and scalable decarbonisation solutions across the built environment spectrum.

EMBODIED CARBON

Accelerator 2030 Goals 30% reduction from a baseline of 387 $KgCO/m^2$*

Propogate
Engage with policy makers, experts, supply chain leaders, contractors and recyclers to help scale low-embodied carbon building materials while fostering awareness about embodied carbon and facilitating capacity building.

Aggregate
Explore possible partnerships for demand aggregation and provide the demand signals to the supply side to mainstream low-carbon products.

Collaborate
Collaborate with innovators to co- create/ improve low-carbon alternatives by offering a platform for iterative adjustments and product/solution adaptation to real-world conditions.

Demonstrate
Deploy low-EC alternative pilots and evaluate material performance and supply-chain capability.
Current focus: Low-carbon concrete mixes with GGB5 and LC3.

Integrate
A comprehensive baselining of EC and prioritising action based on the emission intensity and decarbonisation impact of materials is identified.

REDUCED ENERGY CONSUMPTION

Accelerator 2030 Goals 33% reduction in residential energy usage linked to thermal comfort and water heating form a baseline of 33 KWh/m^2

Propogate
Deliver scalable passive thermal comfort solutions for millions of affordable homes in India. Create awareness and enable 100% adoption of superefficient RACS, Fans and appliances across Lodha's projects

Aggregate
Aggregate demand from consumers for energy-efficient homes and equipment through data-backed awareness programs.

Collaborate
Co-creating with manufacturers to deliver market-ready RAC units and other super-efficient equipment and develop commercially viable solutions for mass adoption.

Demonstrate
Field testing of super-efficient RACS (through GCP) and Fans and informing the captive users about the benefits.
Current focus: Global Cooling Prize AC units, BLDC fans, high performance facade, evaporative cooling and radiant cooling.

Integrate
Benchmark residential energy profile based on field measurements and prioritize performance improvement measures across energy-impacting layers, namely ambient, envelope, internal loads, and user behavior.

CLEAN ENERGY

Accelerator 2030 Goals	Enable 100% RE transition for Lodha's residents using various RE procurement pathways

Propogate
Disseminate learning through RE procurement handbooks and deliver a blueprint of achieving a comprehensive RE transition.

Aggregate
Enable aggregation and integration of energy demand and generation for accelerated RE adoption.

Collaborate
Collaborate with policymakers and RE developers to adopt novel least-cost RE transition models for various use cases.

Demonstrate
Deploy various RE procurement pathways in all energy use cases for Lodha's own operations and for its residents.
Current focus: Rooftop Solar, Open Access, Net Metering and Community Solar.

Integrate
Assessment of Lodha’s electricity demand on the portfolio level. Feasibility assessment for Community Solar projects.

AVOIDED EMISSIONS

Accelerator 2030 Goals	Enable 100% electrification of shared transportation in Palava and catalyse the adoption of private 4W (50%), and 2W (64%) electric vehicles.

Propogate
Deliver a city-scale replicable model for non-motorised/ electrified transportation.

Aggregate
Aggregate the various modes of mobility (motorised and non-motorised) to reduce transportation emissions, and integrate with the infrastructure plans of the larger Metropolitan region.

Collaborate
Collaborate with the policymakers, charging infra providers and residents to tailor-make solutions in this evolving e-mobility landscape.

Demonstrate
E-bus pilot and phased deployment of public- and private-charging infrastructure.
Current focus: Walkability, Bikeability, E-buses and EV charging infrastructure.

Integrate
Baselining modal breakup of private and public transportation and assessing routes for e-buses, and a progressive charging infrastructure roadmap.

* 2022 Lodha EC baseline for a multi-family high-rise reinforced concrete residential building, respresentingthe bulk of expected urbanisation in India.

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CHAPTER 1

Introduction

GLOBAL BOILING

Climate change presents a pressing and global challenge, shaping our planet's future trajectory with its escalating impact — from rising temperatures and sea levels to extreme weather events. This phenomenon is termed 'global boiling' and serves as a reminder for collective action. Notably, July 2023 was the hottest on record and the third consecutive month in which the global average temperature set a record. This was primarily driven by the unprecedented surge in global greenhouse gas (GHG) emissions due to human activities.

THE RATE AND SCALE OF THE CHANGES IN THE CLIMATE SYSTEM ARE UNPRECEDENTED

Over the past 50 years, the global average temperature has increased faster over the last 2,000 years.

Carbon emissions are at their highest levels for at least 2 million years. In 2019, CO_2 concentration reached about 410 PPM in volume.

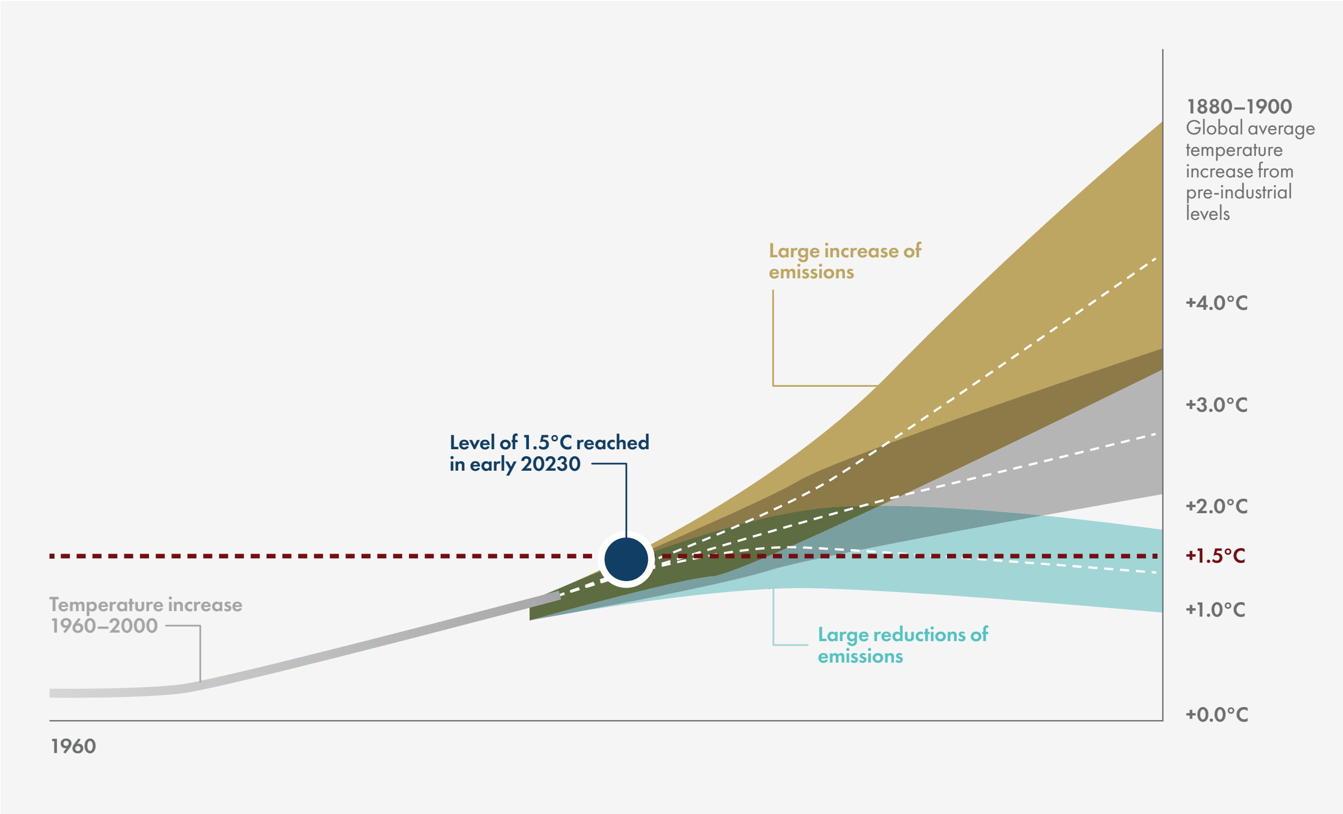
Globally, glaciers have receded faster since 1950 than they have in at least 2,000 years.

GLOBAL EMISSIONS

In 2019, global GHG emissions reached 48,116.5 million metric tons of CO_2 equivalent. Of the major contributors, China, the United States and India collectively account for 42.6% of the total GHG emissions, recording 12,705.1 $MtCO_2e$, 6,001.2 $MtCO_2e$ and 394.9 $MtCO_2e$ of the emissions, respectively. In contrast, the combined emissions of the bottom 100 countries make up a mere 2.9%.

Despite India's prominent position in the list of emitters, its emissions per person are notably lower than those of the other top 10 emitters due to its high population.[1]

EXHIBIT 1.1 **GLOBAL AVERAGE TEMPERATURE HAS RISEN BY 1.1°C FROM PRE-INDUSTRIAL LEVELS**



Source: ?

EMISSIONS FROM BUILT ENVIRONMENT—GLOBAL

The buildings and construction sector is responsible for almost 40% of the energy- and process-related emissions: 28% from operational emissions, mainly the energy needed to heat, cool and power them, and 11% from materials and construction.[2,3] In 2021, CO_2 emissions from buildings operations reached an all-time high of around 10 $GtCO_2$, an almost 5% increase from that in 2020 and 2% higher than the previous peak in 2019.[4]

EMISSION INTENSITY—INDIA

With global CO_2 emissions and GDP rising roughly 6% in 2021, the average emissions intensity of global economic output stayed constant at 0.26 tons of CO_2 per US$1,000.[5] In 2005, India's emissions intensity stood at 0.31 tCO_2 per US $1,000 compared with 0.33 tCO_2 per US $1,000 globally. This intensity was down to 0.25 by 2021[6] due to several factors, including advanced renewable energy (RE), improved energy efficiency and economic growth.

EMISSIONS FROM BUILT ENVIRONMENT—INDIA

Building operations account for about a third of India's energy use. Approximately another 10% is used to produce building materials and construct new buildings. In the absence of peremptory energy-efficiency improvement and policy measures, the buildings sector is estimated to consume over three times more energy by 2050 than that utilised today, and carbon emissions are expected to nearly quadruple.[7]

In the next 20 years, India's CO_2 emissions are projected to rise 50% — the most for any country. A key reason is that India's total building space is projected to more than double. Urbanisation is one of the major growth drivers in the built environment, with India's urban population expected to reach 600 million by 2030 from 377 million in 2020.[8] Estimates suggest that 40–50% of the resources extracted globally are used for housing, construction and infrastructure materials, and about 20–25% of India's total energy demand comes from the manufacturers of building materials.

CHANGING LIFESTYLES

The changing lifestyle of Indians also drives growth in the built environment. Their increasing affluence is leading to considerable demand for energy-intensive goods and services such as air-conditioners (ACs) and EVs.

URBAN HEAT

Growth in the built environment contributes to the urban heat island effect, wherein urban areas are warmer than surrounding rural areas. Buildings and other infrastructure absorb heat from the sun and release it slowly, trapping it in the urban environment. This phenomenon can lead to several health issues, such as heat stress and heat strokes. The projected doubling of India's building infrastructure in the next two decades accentuates the crucial role of the buildings sector in mitigating GHG emissions.[9]

The ongoing rapid urbanisation will propel the demand for the built environment, thereby stimulating the construction sector, transportation and energy requirements. When aggregated, these factors could result in over 60% of the direct or indirect emissions from the building infrastructure.

MATERIAL DEMAND

The manufacture of building materials is resource- and energy-intensive. India is the second-largest producer of bricks, steel and cement in the world. Reinforced concrete and steel frames underpin most of the construction in India's buildings today — around 60Mt of cement and 14Mt of steel were consumed by India's urban construction in 2020.[10]

AC GROWTH

The use of ACs is one of the fastest growing sources of energy demand in India. While 8% of the current Indian households have room ACs, this is predicted to grow six-fold in less than 20 years.[11] This is driven by the increasing heat and humidity besides improving economic conditions in India

This presents a significant and promising opportunity for the buildings sector to not only combat climate change but also yield far-reaching advantages beyond that realm.

ROLE OF BUILDINGS IN ACHIEVING VARIOUS POLICY AND INDUSTRY TARGETS

India's NDC commitments

India's nationally determined contributions (NDCs) exemplify its resolute commitment to emissions reduction and sustainable transformation. NDCs encompass a 45% drop in the GDP emissions intensity by 2030 compared with that in 2005, achieving 50% cumulative non-fossil-fuel-based electric power capacity and sourcing 40% of the electricity generation from renewables. This requires an annual deployment of over 50GW of RE, which is a massive challenge as the country has had a maximum auction of only 30GW of the annual RE capacity awarded thus far.

The buildings sector's pivotal role lies in its capacity to significantly enhance energy efficiency and integrate RE sources. Through advanced technologies, innovative design strategies and widespread retrofitting, the sector can tangibly contribute to emissions reduction, aligning seamlessly with the target to reduce GDP emissions intensity by 45%.

Furthermore, the sector's active involvement in deploying rooftop solar panels, wind turbines and other RE systems within building designs can accelerate progress towards the 50% non-fossil-fuel-based electric power capacity goal. By embracing solar photovoltaic systems, solar water heaters and energy storage solutions, the sector can drive substantial contributions towards achieving RE generation of 40%.

In essence, the buildings sector is a vital conduit for translating India's NDC commitments into concrete actions. The energy-efficient practices and RE integration it embraces not only advance the nation's environmental aspirations but also pave the way for a sustainable and resilient future.

India's EV targets

India's commitment to the global ***EV30@30*** campaign and its ambitious RE goals underscore a pivotal step towards achieving its NDC commitment and striving for net-zero emissions. Aiming for EVs to constitute at least 30% of new vehicle sales by 2030, India is aligning its transport sector with sustainable growth. The surge in EV adoption in recent years and electric car sales quadrupling to 48,000 vehicles in 2022 reflect a promising trajectory. Furthermore, the substantial presence of electric two- and three-wheelers in the market, including a remarkable lead over China, exemplifies India's progressive stance.

India is tapping into the potential of buildings to drive EV adoption. The Bureau of Energy Efficiency (BEE)'s proactive approach is evident in its meticulous plan to install 46,397 public charging stations (PCSs) in major cities by 2030. This infrastructure will catalyse EV uptake by ensuring convenient and accessible charging options for urban dwellers.[12,13]

Furthermore, the Ministry of Housing and Urban Affairs (MoHUA) has amended the Model Building Byelaws to stipulate that 20% of the parking space in new multi-unit buildings be equipped with EV charging. This integration enhances the feasibility of EV ownership and charging for residents, fostering an environment where EVs seamlessly integrate with daily life.

Buildings at the nexus of EVs and RE

The built environment can play a key role in facilitating India's NDC target of achieving 450 GW of RE capacity by 2030. Buildings have emerged as a pivotal junction where EVs and RE intersect, presenting a promising avenue for sustainable urban development. The cohesion between EVs and RE within the built environment is multi-faceted. Buildings can serve as charging hubs for EVs, alleviating range anxiety and bolstering the EV infrastructure. Simultaneously, they can harness solar power through rooftop photovoltaic installations, generating clean energy to charge vehicles and power buildings. Leveraging these opportunities, India's overall rooftop solar (RTS) market is estimated to be over 120GW,[14] translating into substantial carbon savings and reduced strain on the grid.

Moreover, forward-thinking urban planning can integrate EV charging stations seamlessly into the fabric of buildings, encouraging EV adoption by offering convenient charging options. By capitalising on the projected reduction in EV charging costs due to falling battery prices, this confluence can accelerate India's transition to sustainable mobility while contributing to its RE goals.

The convergence of EVs and RE within buildings not only addresses air quality concerns and carbon emissions but also ushers in a new era of energy self-sufficiency and resilience. It presents a compelling narrative where buildings evolve from passive energy consumers to dynamic generators and distributors. To fully realise this potential, robust policy frameworks, innovative incentives and strategic collaborations are imperative, empowering buildings to emerge as pivotal agents of change in India's journey towards a green and electrified future.

ABOUT LODHA NET ZERO URBAN ACCELERATOR

The Lodha Net Zero Urban Accelerator was launched in collaboration with the RMI India Foundation in July 2022. It is a pioneering initiative that aims to make net-zero the new normal for the built environment, thereby accelerating and maximising the building sector's contribution to India's 2070 net-zero emissions target. The Accelerator focuses on enhancing resilience, health, affordability and access to energy services for all by developing actionable initiatives in five key areas: embodied carbon, passive design solutions, efficient equipment, clean energy and clean mobility.

EXHIBIT 1.2 **NET ZERO ACCELERATOR OVERVIEW**

NET-ZERO ACCELERATOR

WHAT IS IT?

Collaborations of rare reach, range and expertise:

- **LODHA**
- **RMI INDIA FOUNDATION**

Plus other sector stakeholders:

- Supply Chain and Solution Providers
- Finance and Investors
- Building End-users
- Policy-makers
- DISCOMs

HOW DOES IT WORK?

Craft and deliver innovative initiatives towards Lodha's net-zero committment, using facilitated multi-stakeholder engagement, integrative design, and R&D.

ACTION AREAS	OUTCOMES
INTEGRATE	Create whole-system roadmaps and tactical playbooks for portfolio decarbonisation.
DEMONSTRATE	Pilot and assess interventions with high potential to reduce energy and carbon, emphasising whole-systems value.
COLLABORATE	Engage stakeholders around business models, financing or policies/ programmes to accelerate net-zero implementation.
AGGREGATE	Jumpstart market for emerging high-performance equipment and services, achieve critical scale in pilot programmes.
PROPAGATE	Drive a proliferation of net-zero across the industry and policy ecosystem.

WHAT DOES IT ACHIEVE?

INCREASE

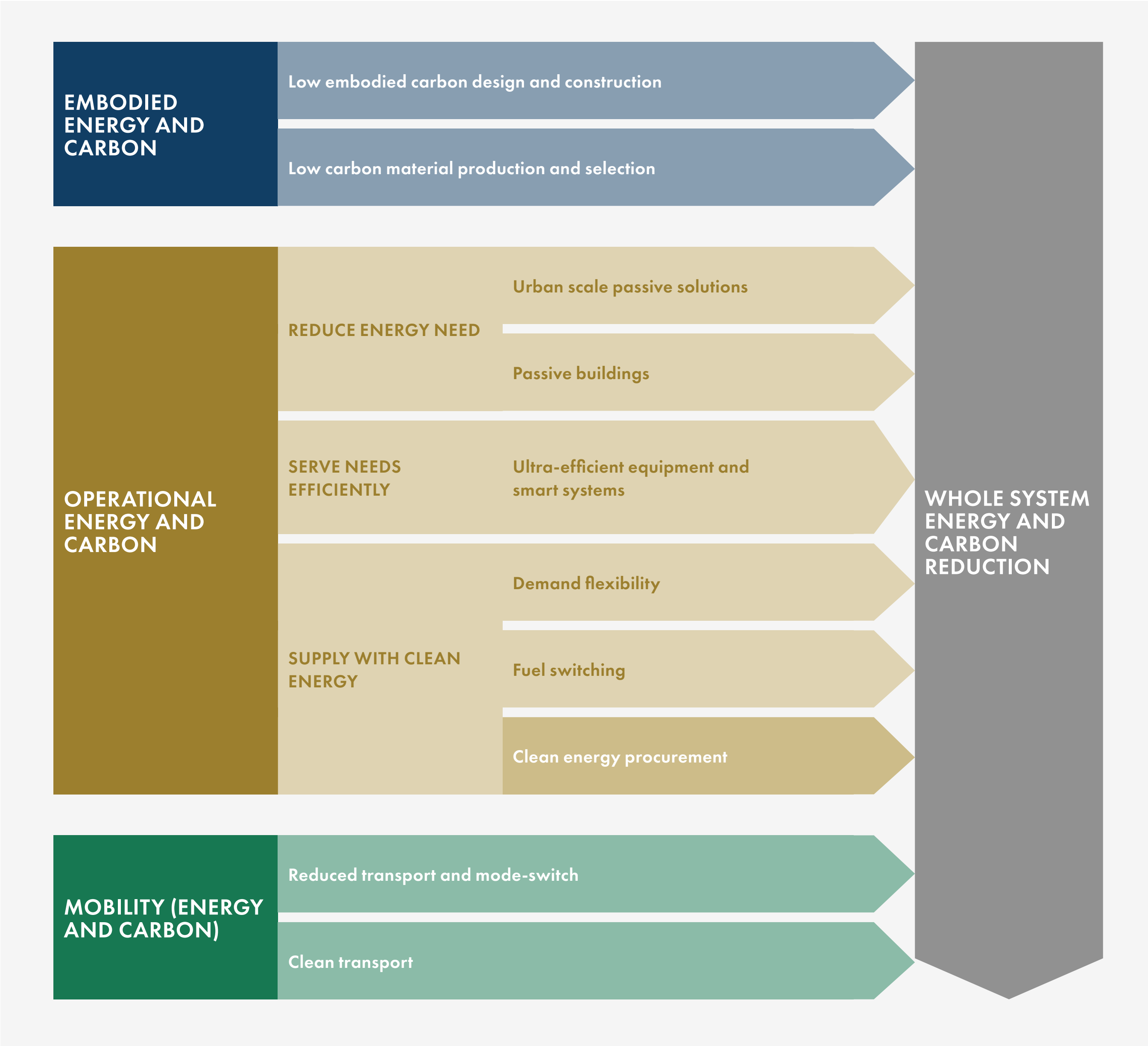
RESILIENCE — HEALTH — COOLING ACCESS — AFFORDABILITY

DECREASE

CARBON — ENERGY COSTS — RISKS — INFRASTRUCTURE COSTS

Lodha's flagship Palava City project will serve as a unique living laboratory for the Accelerator and a lighthouse example by bringing together industry, experts, policymakers and occupants to build integrative sustainable solutions at the city scale. This initiative will enable Lodha to offer a development template that can demonstrate — to India and to the world — that growth decoupled from emissions is possible. It will also be a resource hub and go-to platform for the industry and policymakers charting India's decarbonisation journey.

EXHIBIT 1.3 **WHOLE SYSTEM OF SOLUTIONS AND INITIATIVE FOCUS AREAS**



The Accelerator comprises five categories of activities — integrate, demonstrate, collaborate, aggregate, propagate — that solve challenges for Accelerator partners, with concurrent goals of replicability and market scaling. The activities support each other and can occur in parallel.

While the projects follow contemporary green buildings, development guidelines, and recommendations, the Accelerator through its focus areas intends to offer complementary approaches, data, and research that not only strengthens the green net-zero buildings momentum but gives its information to evolve the program in partnership with a larger set of stakeholders and taking a market-based approach.

1

Integrate

Create a whole-system roadmap to achieve net-zero, calibrated to the portfolio across emissions scopes 1, 2, 3 and 4. Integrate uses system thinking to scope and prioritise initiatives within focus areas, as indicated in Exhibits ES2 and ES3.

2

Demonstrate

Pilot and assess tactical interventions with high potential to reduce energy consumption and carbon emissions in new developments across various scales such as city, neighbourhood, building, household and equipment. Emphasise elevating hidden value across intervention areas: embodied carbon, planning, integrative design, superefficient equipment, smart systems, end-user behaviour and clean energy supply. Create a knowledge base of successful implementation and value of emerging and whole-system, integrative solutions, informing corporate practices and providing case studies for the broad industry.

3

Collaborate

Engage stakeholders to identify new business models, financing innovations or targeted policies/programmes to accelerate net-zero implementation with replicability and scalability potential across India's built environment. To realise new value, emphasise engaging stakeholders outside the conventional boundaries of project planning and execution, such as utilities, finance, investors, policymakers, city planners and key actors in supply chains. Stakeholder engagement also includes end-users and occupants as active participants in a net-zero future.

4

Aggregate

Jumpstart markets by organising bulk demand for leading edge equipment, materials or services, improving availability and de-risking new products for all major stakeholders. Demand aggregation also forges a path for 'fast-followers,' which can result in additional cost compression and a level playing field between industry players.

5

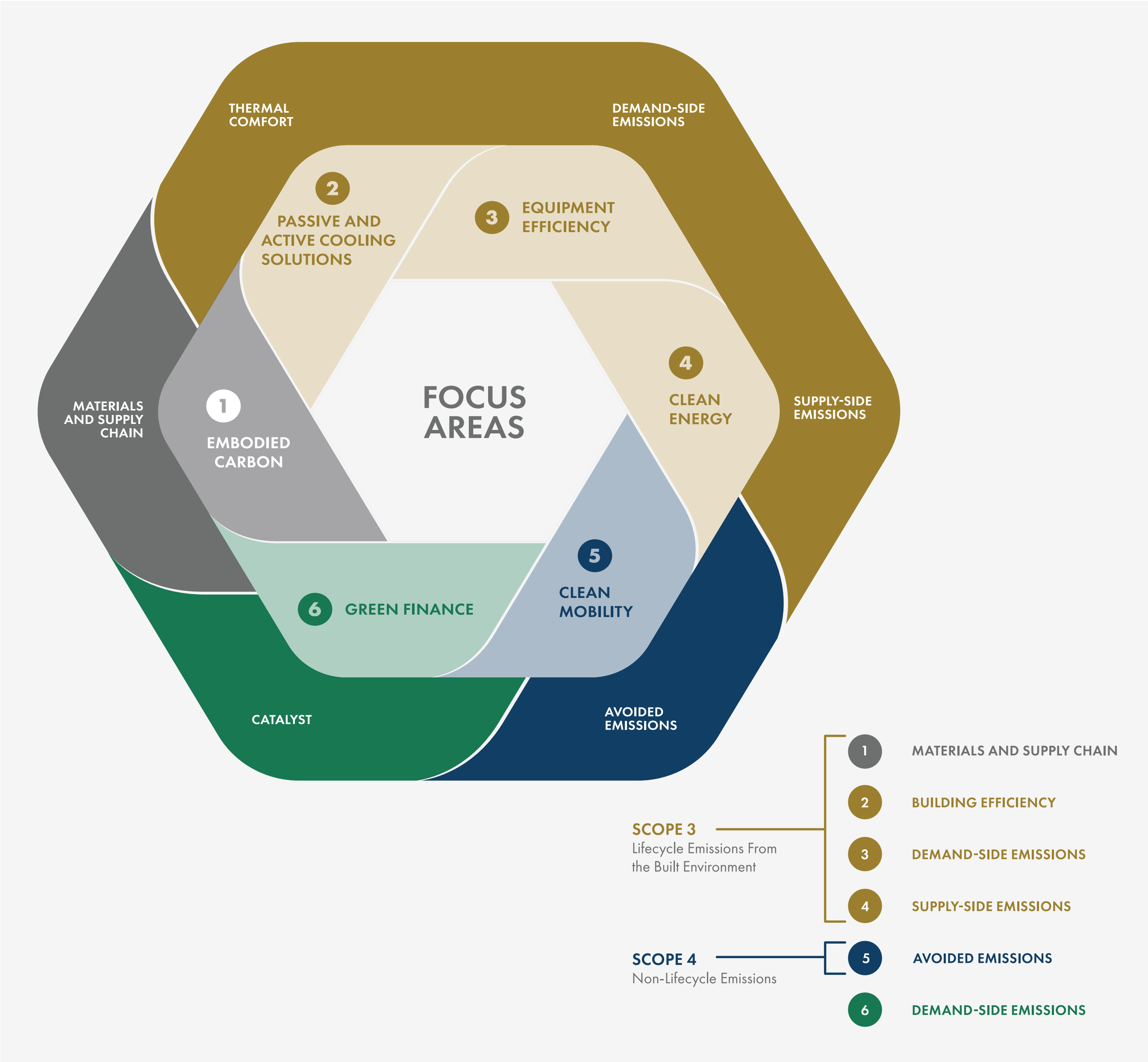
Propagate

Drive proliferation of net-zero commitments by more industry players and policymakers across India's buildings sector. This will improve solution economics, ease implementation, prevent counterproductive regressions in the marketplace and generate momentum toward an accelerated net-zero transformation of the buildings sector.

The overall vision of the Accelerator is to create and sustain a market for thermally comfortable net-zero carbon built environment in India.

To achieve the broad vision and address the emissions spectrum of the built environment, as shown in the exhibit below, the Accelerator focuses on the following key areas:

EXHIBIT 1.4 **APPROACH TOWARDS FOCUS AREAS BY LODHA NET ZERO URBAN ACCELERATOR**

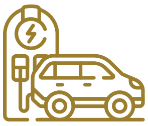


As depicted in the above section, the Accelerator focuses on Scopes 1, 2, 3 and 4 emissions, and the exhibit on the next page details the activities taken up by the Accelerator in its first year.

TABLE 1.1 INSIGHTS INTO THE ACCELERATOR'S THEMATIC AREAS

FOCUS AREA	WHY	WHAT	HOW	ACCELERATOR'S CURRENT FOCUS
Embodied carbon	Of the global emissions, 30% originate from the industry, of which one-third is just from building material production. Unprecedented urbanisation and infrastructure growth in India in the coming decades will lock in immense carbon upfront.	We use low-carbon materials, especially those with the highest impact, namely, cement, concrete, steel, aluminium, glass, blockwork and tiles (almost 75% of the embodied carbon).	1. Conducting embodied carbon baselining and identifying optimisation opportunities by intelligent design and reduction of redundancies 2. Engaging with the industry and undertaking pilots for green materials 3. Creating an ecosystem that tracks and reduces waste and identifies reuse streams	1. Green concrete mixes — with GGBC and LC3 2. Recycled steel vendors on embodied carbon data and quality 3. Saving aluminium by developing a central formwork yard in-house and changing the demand dynamic of formwork through component-based designs rather than typology-based designs 4. Engaging with steel and Al vendors for EPDs and share of the recycled input
Thermal comfort (Envelope and natural ventilation)	The frequency, intensity and duration of heatwaves is expected to rise globally as a consequence of climate change, i.e. temperatures are slated to rise in the future, worsening the heat stress in India. India being the most populous country, this will have a dire impact on the following: 1. Health and well-being of people 2. Energy demand and sustainability 3. Productivity and economic growth	To address the issues of rise in temperature and energy demand, we have the following goals: 1. Accessibility to information on strategies and solutions to improve thermal comfort 2. Increasing affordability of next-generation cooling solutions	To achieve the broad goals of thermal comfort, making information accessible to people and ensuring accelerated affordability through the pilot and scale model for the Accelerator/Palava, we focus on the following: 1. Work directly with academics and experts 2. Help policymakers with studies and pilots 3. Inform and engage consumers through data and awareness campaigns	1. Satellite studies on the urban heat island effect (cooling through greenery and high reflective paints) 2. Envelope performance — glass and walls mean radiant temperatures and solar heat gains 3. Aids for natural ventilation (windows, masterplans and solar chimneys)
Reduced energy demand	By 2030, India will have twice the number of cities with million-plus population than Europe does, housing double the current US population. Increase in affordability through economic growth is expected to raise the energy demand exponentially. This growth needs to be decoupled from emissions.	1. Cooling and thermal comfort needs maximum energy demand in residential and commercial segments 2. Quick shift to super-efficient equipment 3. Scale to be used to tunnel through the cost barriers of these innovative technologies	1. Work with industry (e.g., GCP) and innovators to test and validate the technologies 2. Co-develop technologies and specifications that can be made commercially viable through Lodha's direct or indirect demand 3. Create a movement to increase demand through direct market transformation or policy support	1. Global cooling prize – next-generation AC machines; tests are underway in Palava 2. Accelerate BLDC fan demand
Clean energy	India aims to reduce its GDP emissions intensity by 45% by 2030 from that in 2005 and achieve 50% of the cumulative electric power installed capacity from non-fossil-fuel-based energy resources by 2030. While regulations and policy will increase this demand, the industry should also accelerate the demand and inform policy on where support is needed.	1. Residential electricity demand will overtake all other categories (commercial, industrial, agriculture, etc.) of electricity needs by 2040 2. With rapid urbanisation and limited roof capacities of high-rise buildings, generating most of the electricity through renewable means at site is impossible 3. Renewable intermittence requires multiple sources or storage as necessary pairing for the solution 4. While there are policies in place to procure RE from grid off-site, enough regulations to enable all loads, small or large, to be switched to RE do not exist	1. Deploy RE through all available procurement models 2. Maximise on-site solar energy through smart building and terrace designs 3. Explore models that can be made viable for individual consumers presently living in a 'solar eclipse'	1. Deploy the open access renewable purchase model for most of the load qualifying under Green Open Access Rules 2022, pending implementation in Maharashtra 2. Maximise rooftop solar 3. Conceptualise community solar through virtual net metering for a large number of residential consumers

TABLE 1.1 **INSIGHTS INTO THE ACCELERATOR'S THEMATIC AREAS (CONTINUED)**

FOCUS AREA	WHY	WHAT	HOW	ACCELERATOR'S CURRENT FOCUS
 **Electric vehicles**	Up to 20% of the emissions come from transportation, with almost half from private vehicles. The Government of India has initiated a major push towards EVs, a two-step solution of transport electrification and electricity greening	1. Reduce unnecessary transportation 2. Rapidly electrify private transportation by providing access to charging infrastructure such that it catches up with grid greening 3. Increase the use of public, shared transportation instead of private	1. Wide streets for walkability and cycling; placemaking that brings daily needs closer (Palava 5-10-15 model) 2. Shared mobility through buses, shared bikes, etc. 3. Connectivity to public transportation and major working hubs	1. Electrification of buses 2. Creation of model EV charging infrastructure to accelerate EV uptake

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CHAPTER 2

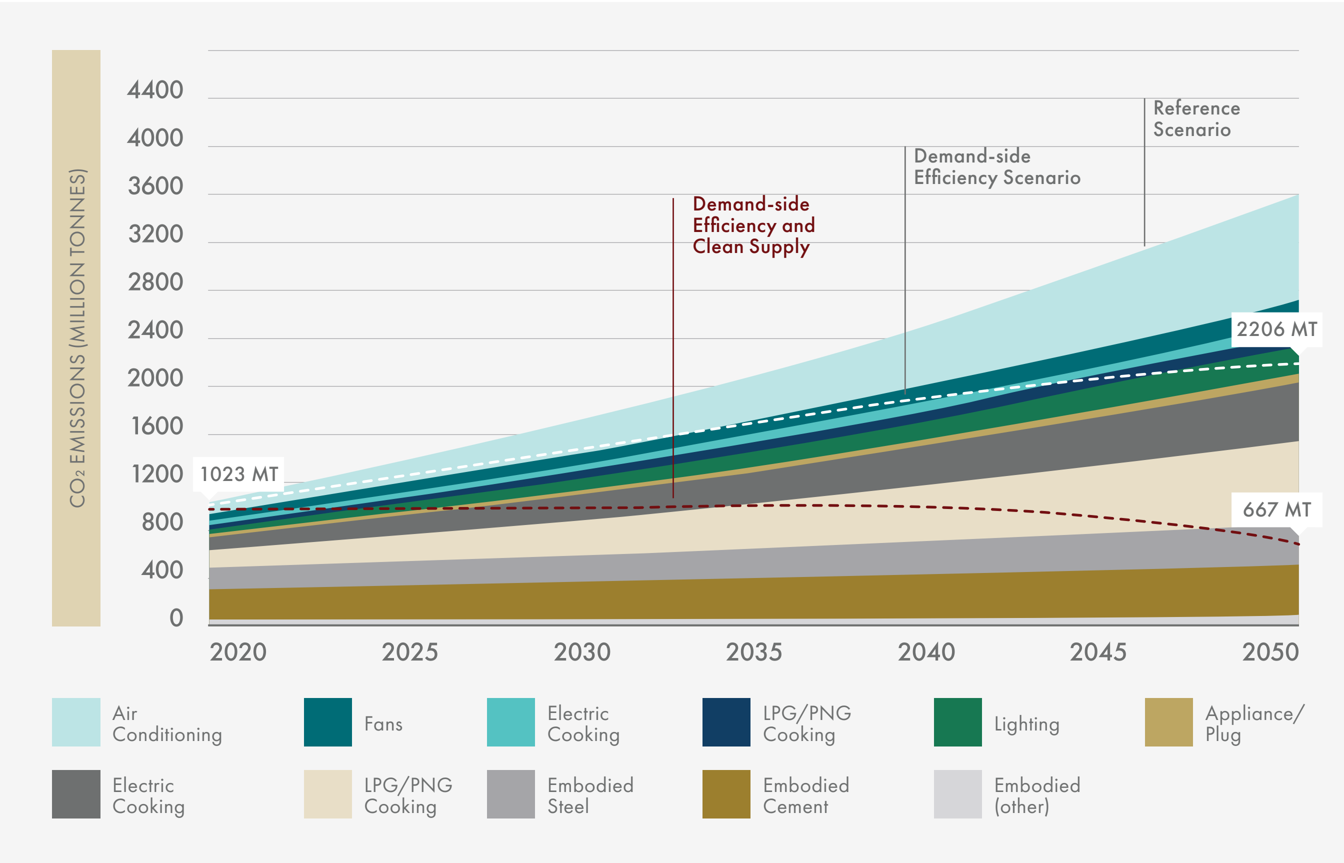
Electricity Use Baseline in Residential Buildings: Initial Study of Palava's Electricity Data

CONTEXT

The buildings sector is currently one of the largest emitting sectors in India. Building operations already account for a third of the country's total emissions. Furthermore, the majority of India's built environment is yet to be constructed. Thus, at the current pace, the energy consumption and emissions of the buildings sector are expected to increase threefold by mid-century,[1] significantly eating into India's NDC aspirations of reducing carbon intensity by 45% by 2030 (compared with 2005), eliminating 1 billion tonnes of emissions by 2030 and achieving net zero by 2070.[2]

However, this trajectory is uncertain, and there is opportunity to cut emissions intensity through several interventions that can improve the energy efficiency and reduce emissions intensity of the built environment. Energy-efficient building design, appliances, and operation can reduce the 2050 building energy use in half, presenting an opportunitytoday to redirect the buildings sector away from the business-as-usual emissions trajectory.

EXHIBIT 2.1 **BUILDINGS SECTOR CARBON EMISSIONS THROUGH 2050, WITH REDUCTION POTENTIAL FROM ENERGY EFFICIENCY MEASURES**



Source: National Institute of Urban Affairs and RMI's report, "From the Ground Up."[3]

To accelerate the transition towards net-zero buildings and promote industry collaboration the Lodha Net Zero Urban Accelerator is allowing, allowing stakeholders to test, evaluate, and scale technologies, business models, financing and programmes that can be employed in future built environment construction.[4]

While innovative energy efficiency practices are shared across global forums and becoming more widespread, the buildings sector requires more data-driven examples based in India to understand the true energy performance of residential buildings. Energy performance data is critical to design effective energy efficiency policy standards and market incentives. For instance, the US Energy Star Programme is based on a set of performance data in the United States, which, in turn, has informed the Leadership in Energy and Environmental Design (LEED) building standards.

However, regionally specific data and standards are necessary to not only incorporate variability in climatic conditions but also existing construction precedent and consumption norms. Bureau of Energy Efficiency's (BEE) baselining and star labelling programme have initiated the first important step for establishing the energy performance of residential buildings in India. Additionally, certain design-based standards exist within the buildings sector specific to India, such as the Green Rating for Integrated Habitat Assessment (GRIHA), Indian Green Building Council (IGBC), and International Finance Corporation Excellence in Design for Greater Efficiencies (IFC Edge). However, the current scale of data that can help understand residential building performance in India is limited. For example, GBPN and CEPT's[5] baseline study of building energy consumption in India is one of the few sources of energy performance data in India that include contributing factors such as design and occupant use.[6] With better data availability, the buildings standards in India can be updated to reflect current and aspirational building performance. This is especially needed with growth in new construction, air conditioner penetration, and electric appliance access. This is true in both commercial and residential spaces.

This study has the following objectives as part of the Accelerator:

- Understand the baseline energy consumption of residential flats in Palava and the factors contributing to variability in energy use.

- Identify priority performance improvement measures within Palava by generating quantitative information on energy performance and contribute to the public reference for residential building energy performance in warm and humid climates.

This paper describes available data and context for Palava, initial correlations between EPI and design factors such as number of bedrooms and RACs and the next steps needed to assess the patterns in the data.

ANALYSIS OF PALAVA CITY DATA

Buildings and sample size in Palava

Palava is a greenfield mixed-use development located 45km east of Mumbai near Dombivli. It falls under the hot and humid climate zone classification: in the study period of November 2021–October 2022, the daily average temperatures were 20–33°C, relative humidity average was 70% across the year and peak summer temperature was 38°C.[7] The data presented below is based on one year of monthly flat-level energy consumption data from Maharashtra State Electricity Distribution Co. Ltd. (MSEDCL) from November 2021 to October 2022. Data was collected from Palava's Phase II development, from 9,566 flats, across 17 residential building clusters constructed between 2015-20. However, the energy performance statistics were only looked at for 5035 flats with monthly energy consumption greater than 50 kWh for at least 10 months of the year. The rationale for this subset is described below.

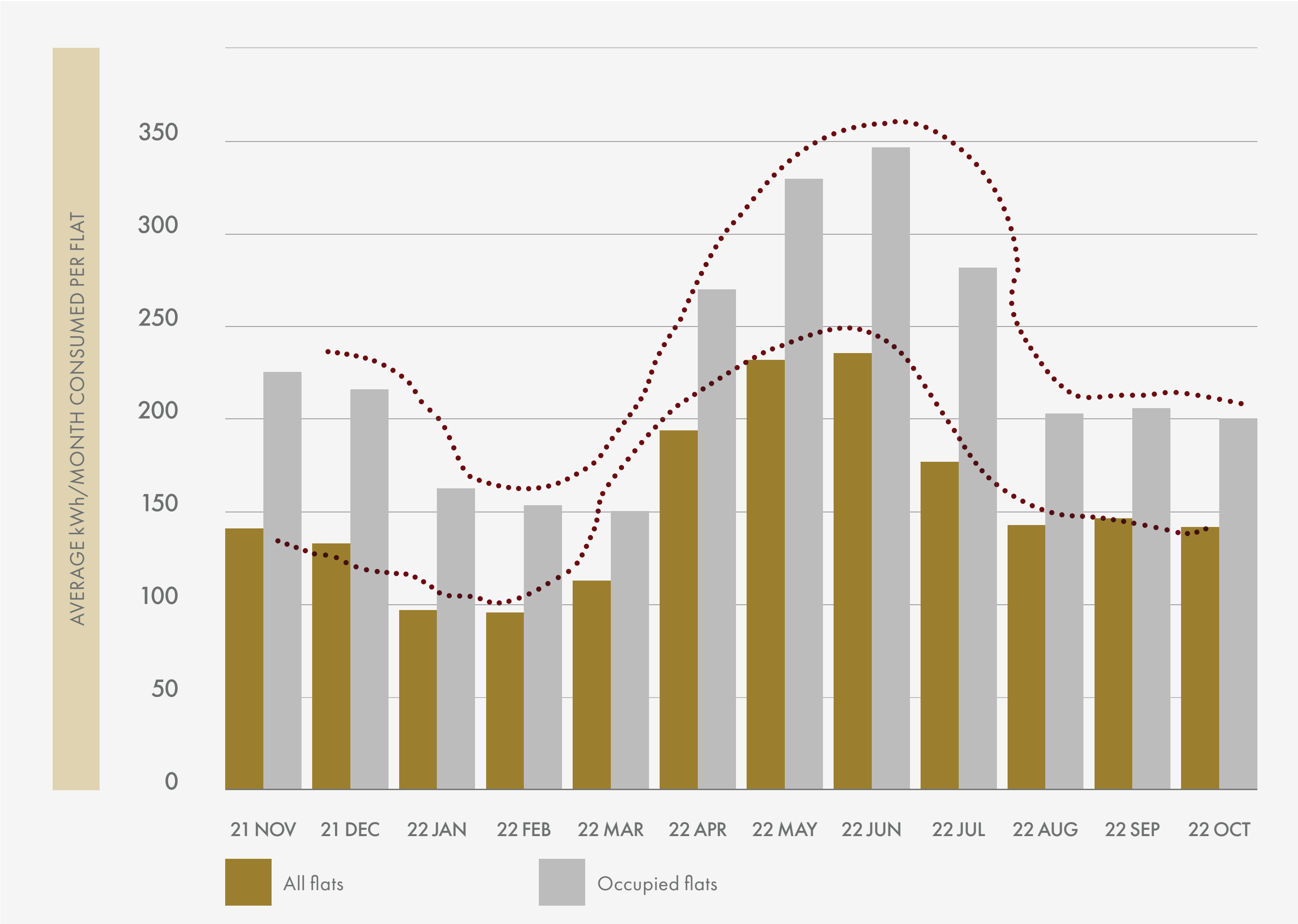
Total energy use and minimum energy use threshold

The total energy used from the 9,566 flats over one year is 16.9GWh. As shown in Exhibit 2.2, seasonal variation shows expected change in energy use likely due to the cooling required for desired thermal comfort. Occupancy also impacts the energy use, as some flats may be unoccupied for part of the year.

To limit the biases caused by partially or entirely unoccupied flats on the trends in these results, this study sets a minimum energy consumption threshold for flats to be considered fully occupied. This threshold is roughly based on average appliance sizes. According to a BEE labelling program estimate, power consumption for 250 L refrigerator is 30–50 kWh for 3-5 star appliances[8], while some recent studies suggest a lower range.[9] The typical refrigerator in India can be up to 50% of the home energy load for some flats.[10] Thus, 50kWh is taken as a rough estimate for minimum power load. Other thresholds were considered and are discussed further below.

An example of these biases in the seasonal consumption variation of the average monthly energy use in Exhibit 2.2, wherein the blue bars represent all flats and the orange bars represent flats with minimum energy consumption of 50kWh. When considering all flats, the average monthly energy consumption increases 83% in summer months (April–June) compared with the winter months (November–January). However, when only considering flats that consume more than 50kWh/month, the increase in energy use from winter to summer is only 55%. This suggests that minimum energy consumption biases the seasonal variation in energy use, which may be attributed to occupancy.

EXHIBIT 2.2 **MONTHLY AVERAGE ENERGY USE FOR PALAVA FLATS STUDIED**

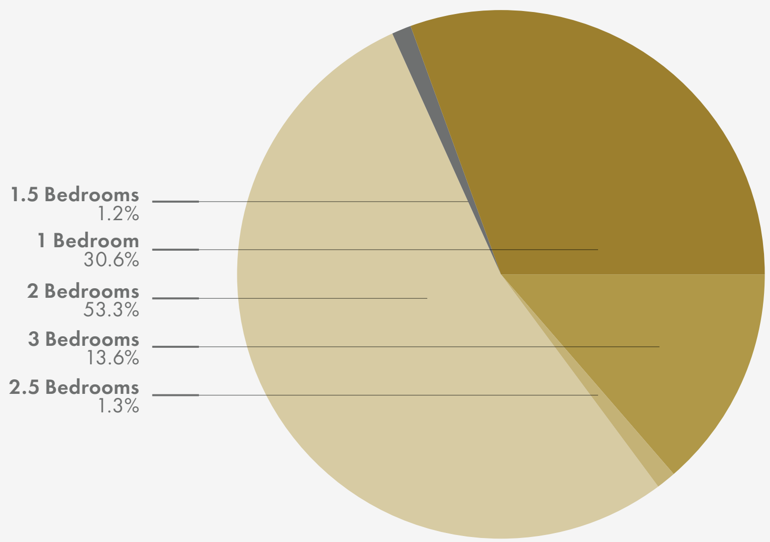


Source: Internal electricty use data.

For this study, occupied flats are considered those with a minimum of 50kWh for at least 10 months of the year. Some gaps in occupied months are expected due to rental unit turnover.

The exhibits on the following pages represent data for occupied flats alone (5,035 flats). The total energy consumption is 12.3GWh/year, or 2,456kWh/flat/year on average. These flats have the following distribution of sizes and energy performance index (EPI) values, shown in terms of flat types and areas.

EXHIBIT 2.3 **DISTRIBUTION OF BEDROOM COUNTS**



Note: More than 50% of flats are two-bedroom, with some distribution of one- and three-bedroom flats as other major categories

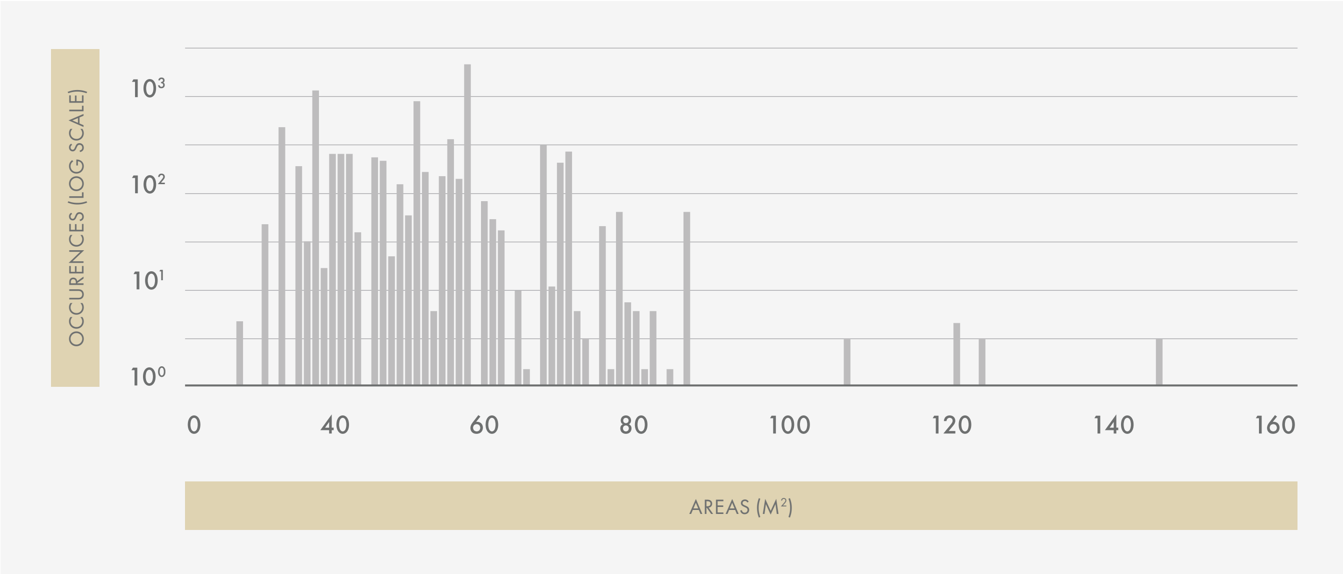
Flat size and EPI values

As shown in Exhibit 2.5, 1st to 99th percentile EPI values across occupied flats vary from 10 to 95kWh/m²/year. The median EPI is 34kWh/m²/year, with a significant spread — standard deviation of this distribution is 19kWh/m²/year, noting that this distribution does not control for flat size or other factors. The distribution has a long tail owing to several outliers of high energy usage per month.

Average EPI is calculated by dividing the annual energy use against the flat area. In order to isolate thermal comfort system energy use in this study, the EPIs are then reduced by 7 kWh/m²/year, as an approximation for non-cooling appliance energy load suggested from BEE's Residential labelling programme schedule.[i]

i. https://beeindia.gov.in/sites/default/files/Schedule%20-%20Residential%20building%20labelling.pdf

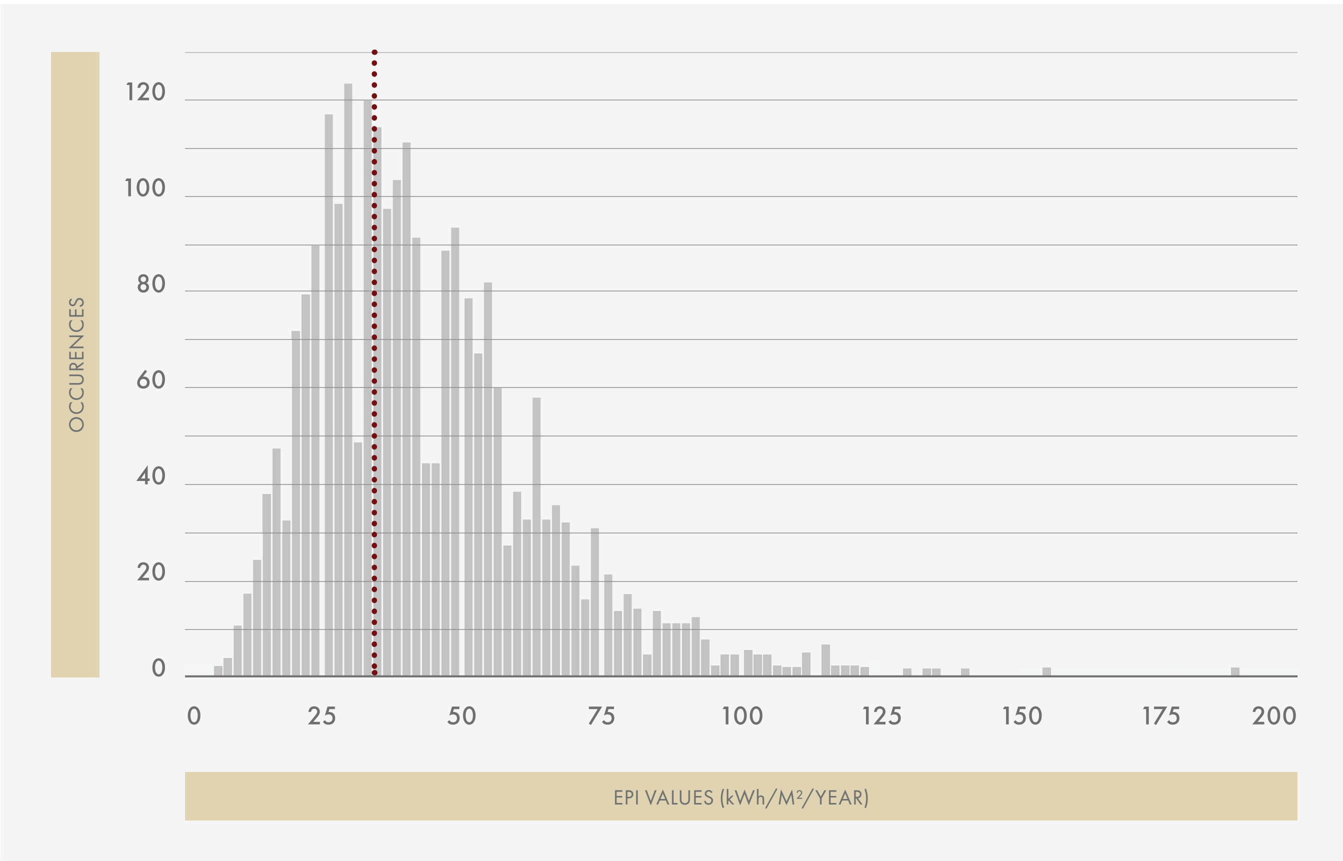
EXHIBIT 2.4 **DISTRIBUTION OF FLAT AREAS ACROSS OCCUPIED FLATS.**



Note: Most flats have an area of 42–62M, smaller than the average new flat construction in Mumbai in 2023.

Source: Business Insider[11]

EXHIBIT 2.5 **DISTRIBUTION OF EPI VALUES (KWH/M²/YEAR) ACROSS OCCUPIED FLATS.**



Correlation of energy consumption with design factors

The EPI of each flat was compared with the flat area, bedroom count, floor number and primary orientation. Each of these individual factors had limited correlations with EPI on aggregate.

EPI has a weak negative correlation with flat area (see Exhibit 2.6 below) and connected load (see Exhibit 2.7 on the next page). A possible reason for this is that the marginal energy consumption increase from additional bedrooms and appliances per flat is outweighed by the floor area increase per bedroom relative to the living space energy consumption. The correlation with connected load needs to be investigated using surveys to understand how actual appliance load and use compares with the nominal sanctioned load of the flats. This study also analysed correlations with bedroom count, floor number and primary orientation; these correlations can be found in the appendix.

EXHIBIT 2.6 **CORRELATION OF EPI WITH AREA AND FLAT PRODUCT TYPE**

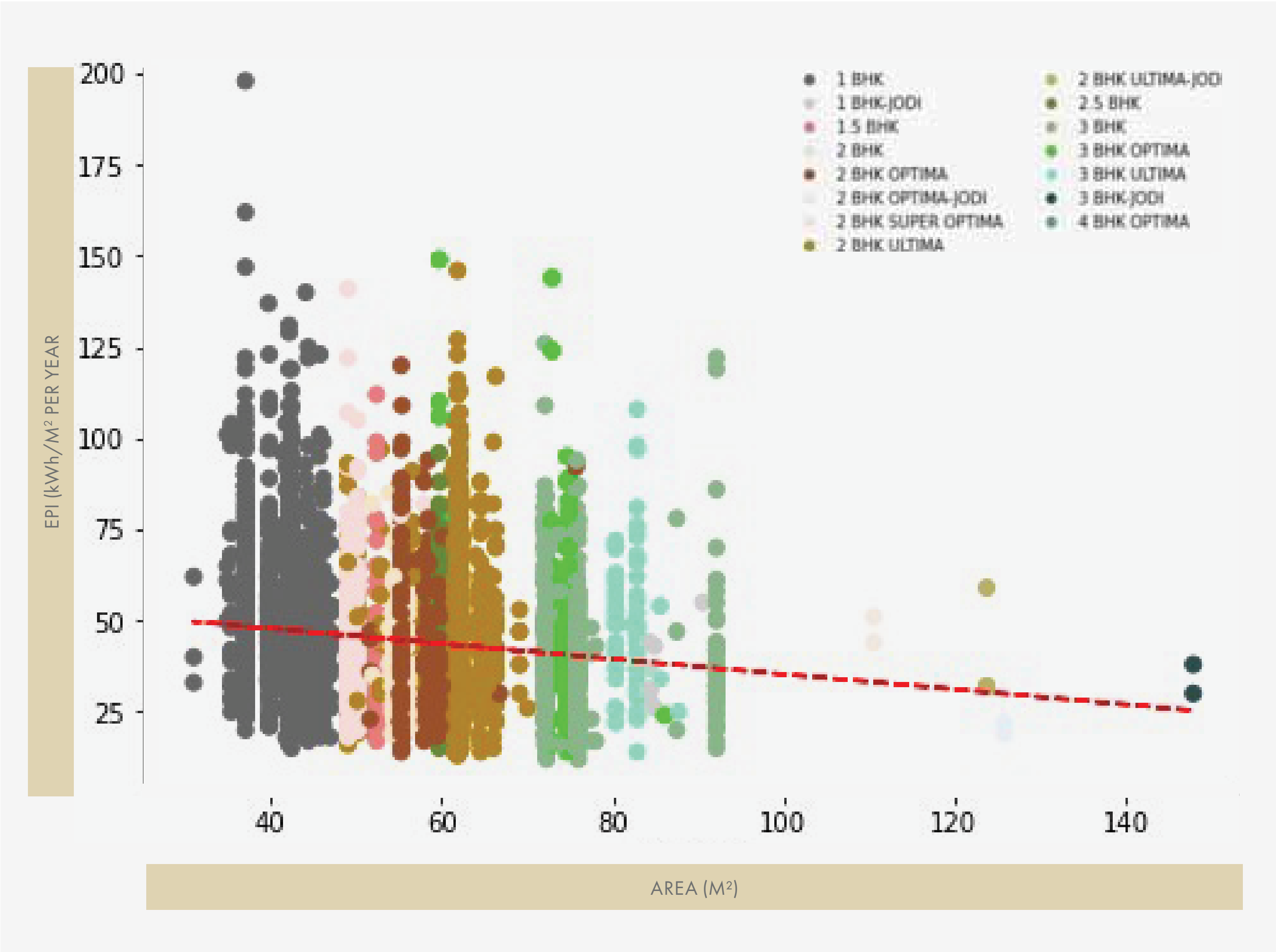
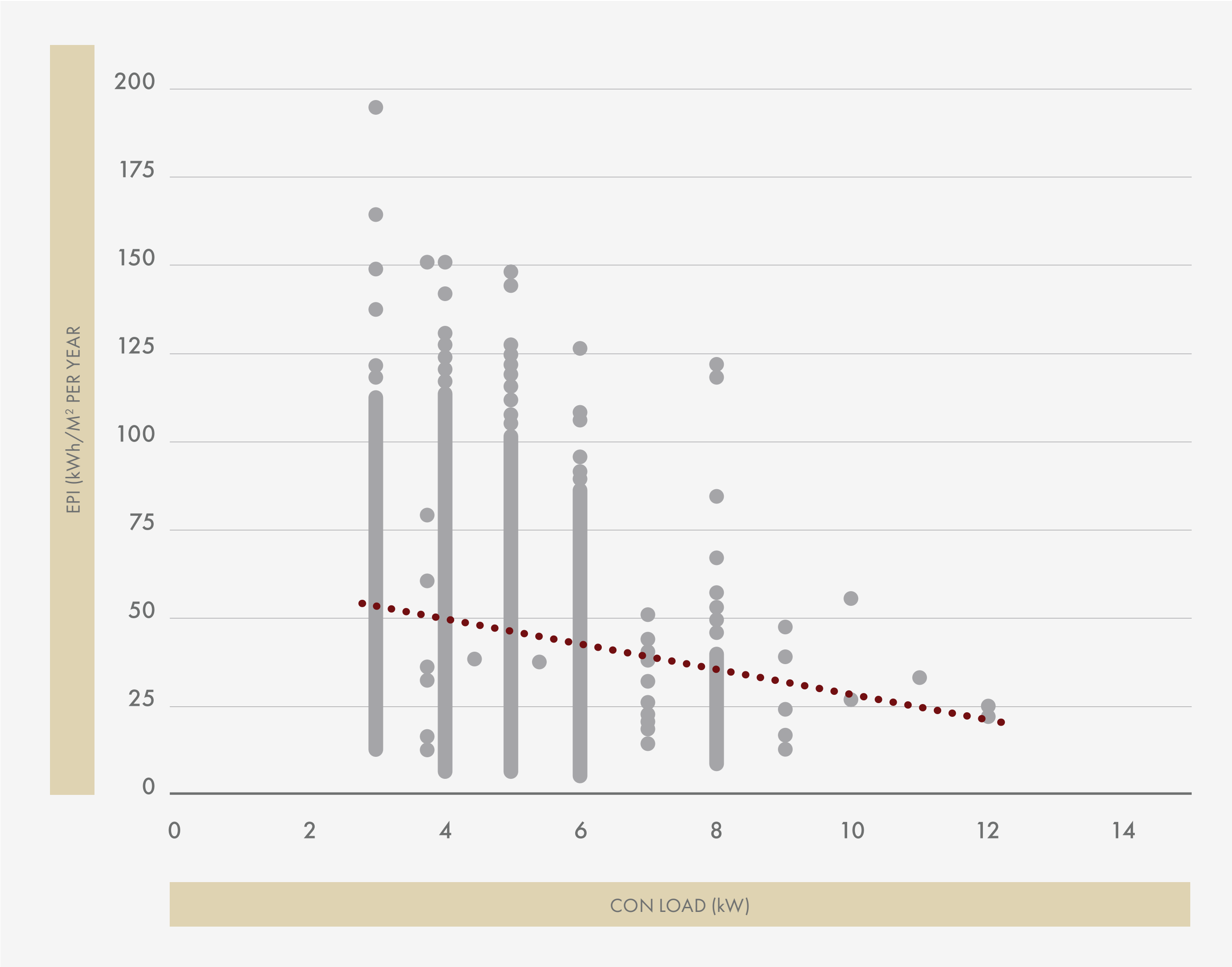


EXHIBIT 2.7 **CORRELATION OF EPI WITH CONNECTED LOAD**

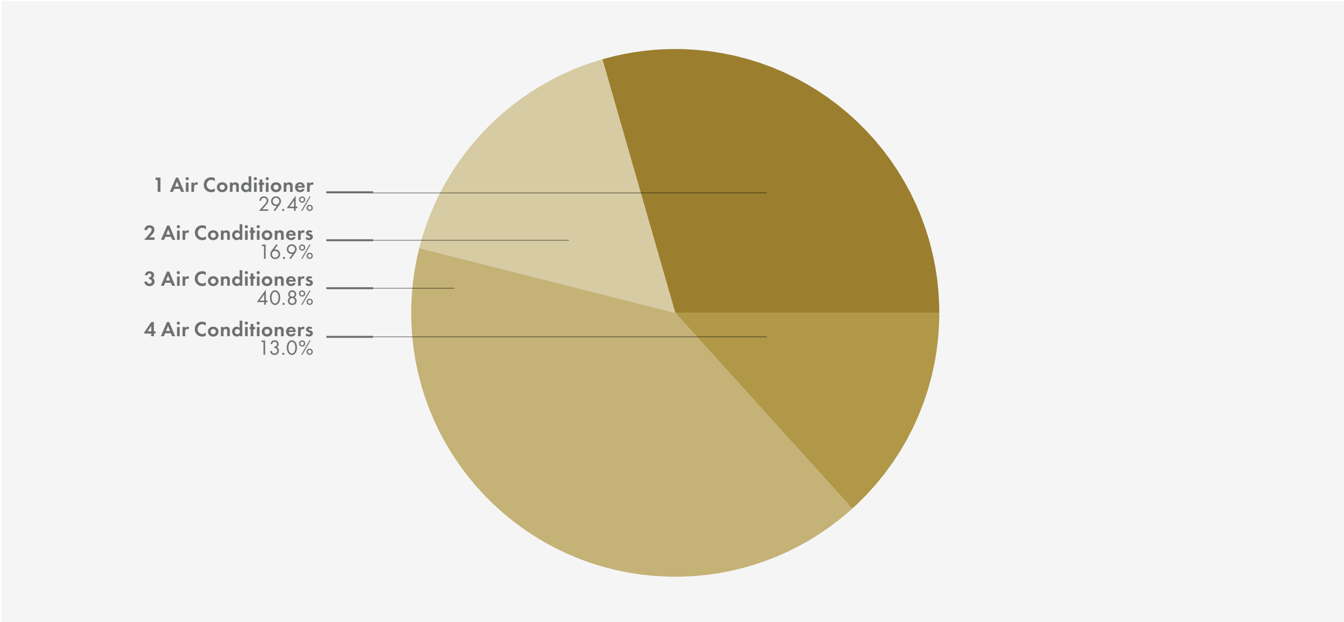


AC variation

Each flat is known to have at least one-bedroom split air conditioning (RAC) unit, with some flats having more. The ISEER rating and size of each unit vary based on the date of installation, all falling within 3.2–5.24 ISEER and 0.75–2.0 tonnes of refrigeration. The 100% RAC penetration is a reflection of new construction patterns and expectations of access to cooling, contrasting the average household RAC penetration in India of under 10% in the population.[12]

The percentage of flats with one RAC unit is proportional to the number of one-bedroom flats in the data set. However, more than half the flats have at least three RAC units, suggesting a larger proportion of flats with more RAC units than bedrooms (i.e. living room and study RACs) in two- and three-bedroom flats.

EXHIBIT 2.8 **PERCENTAGE OF NUMBER OF ROOM AIR CONDITIONERS PER HOUSEHOLD**



EPI vs. number of room air conditioners

The relationship between flat EPI and AC unit information is indicated in Exhibits 2.9 and 2.10. There is a weak decreasing trend in the average EPI vs AC count, with wide EPI distributions under each count. EPI values may stabilise with respect to AC count after the count reaches at least three,[13] which might limit the trends that can be understood from the aggregate-level study prior to controlling for bedrooms and use patterns. EPI and primary bedroom RAC EER are weakly positively correlated, with similarly wide EPI distributions under each EER value. This positive correlation may be attributed to use patterns and needs to be investigated further.

EXHIBIT 2.9 **AVERAGE EPI FOR FLATS WITH DIFFERENT NUMBERS OF ACs**

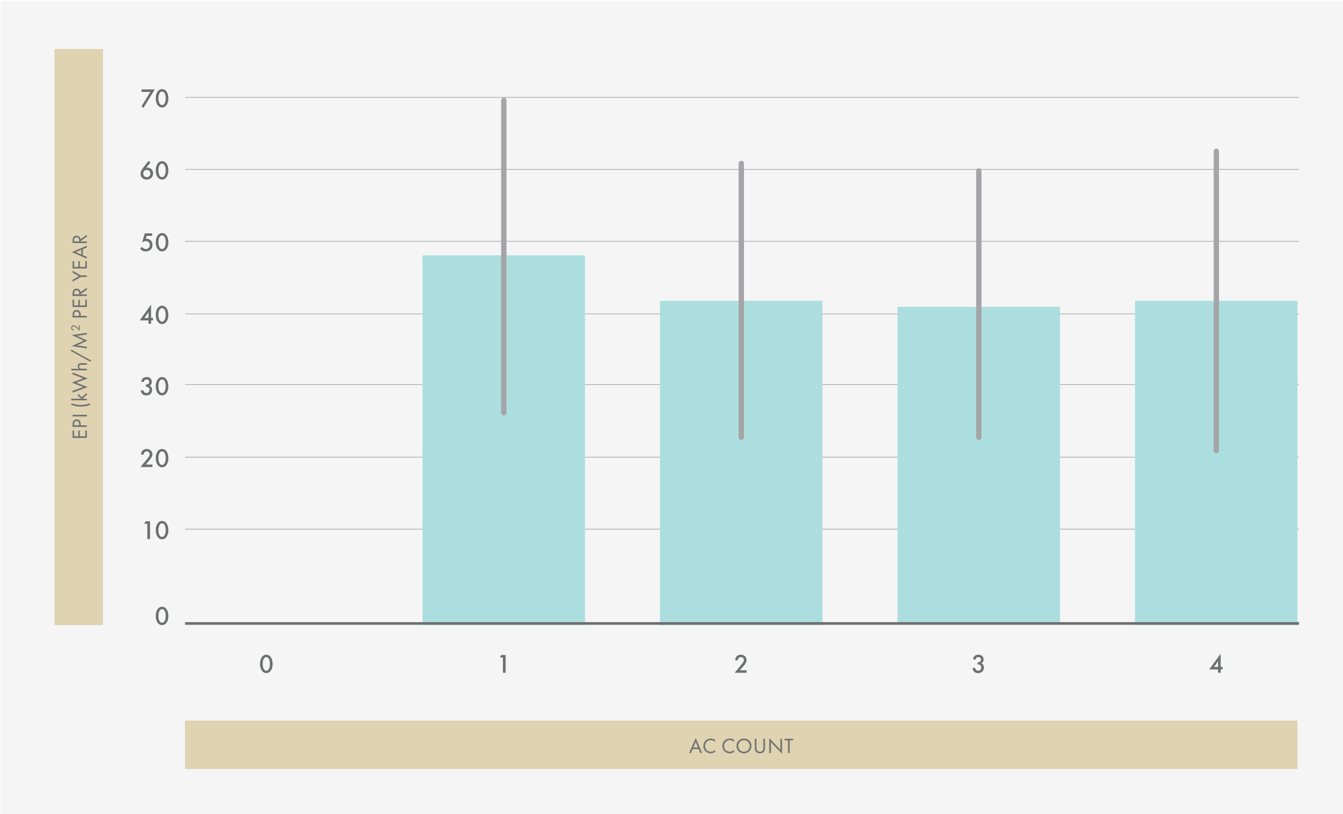
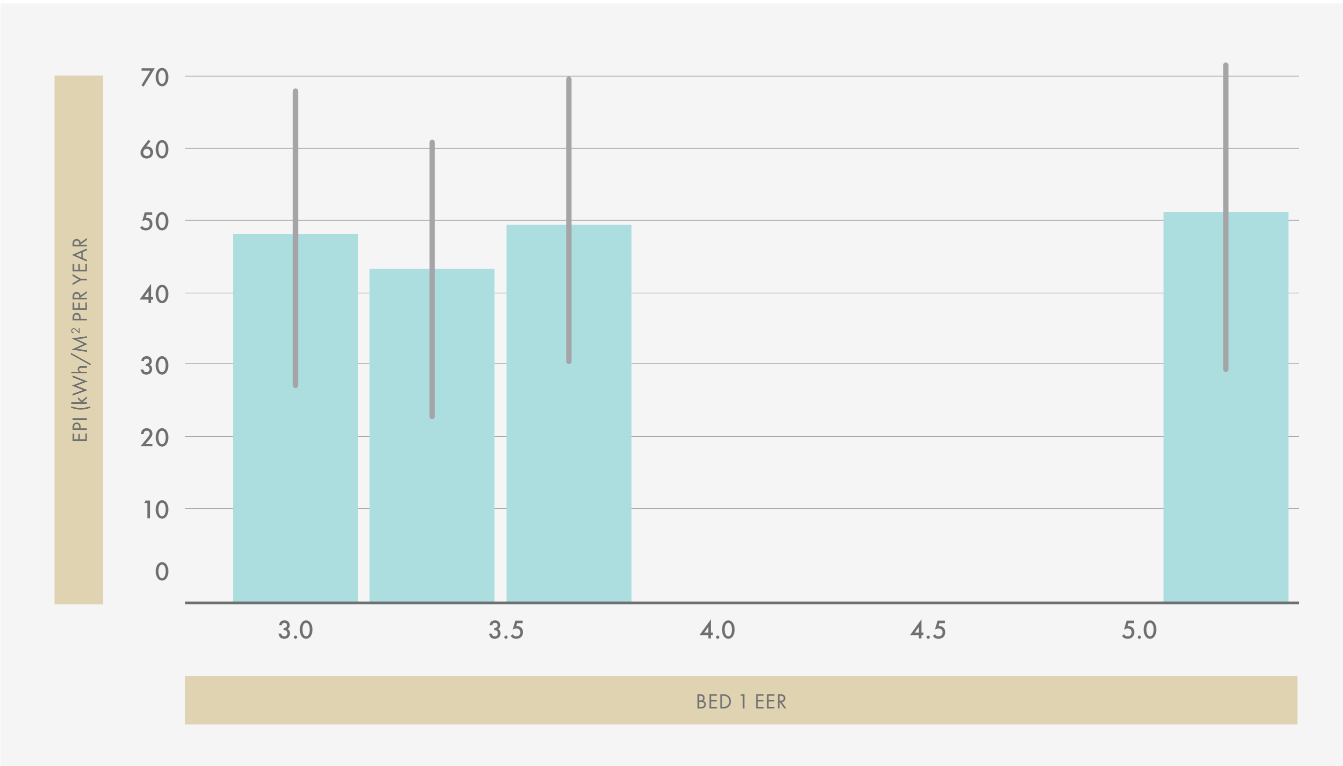


EXHIBIT 2.10 **CORRELATION OF PRIMARY BEDROOM RAC EER WITH EPI**

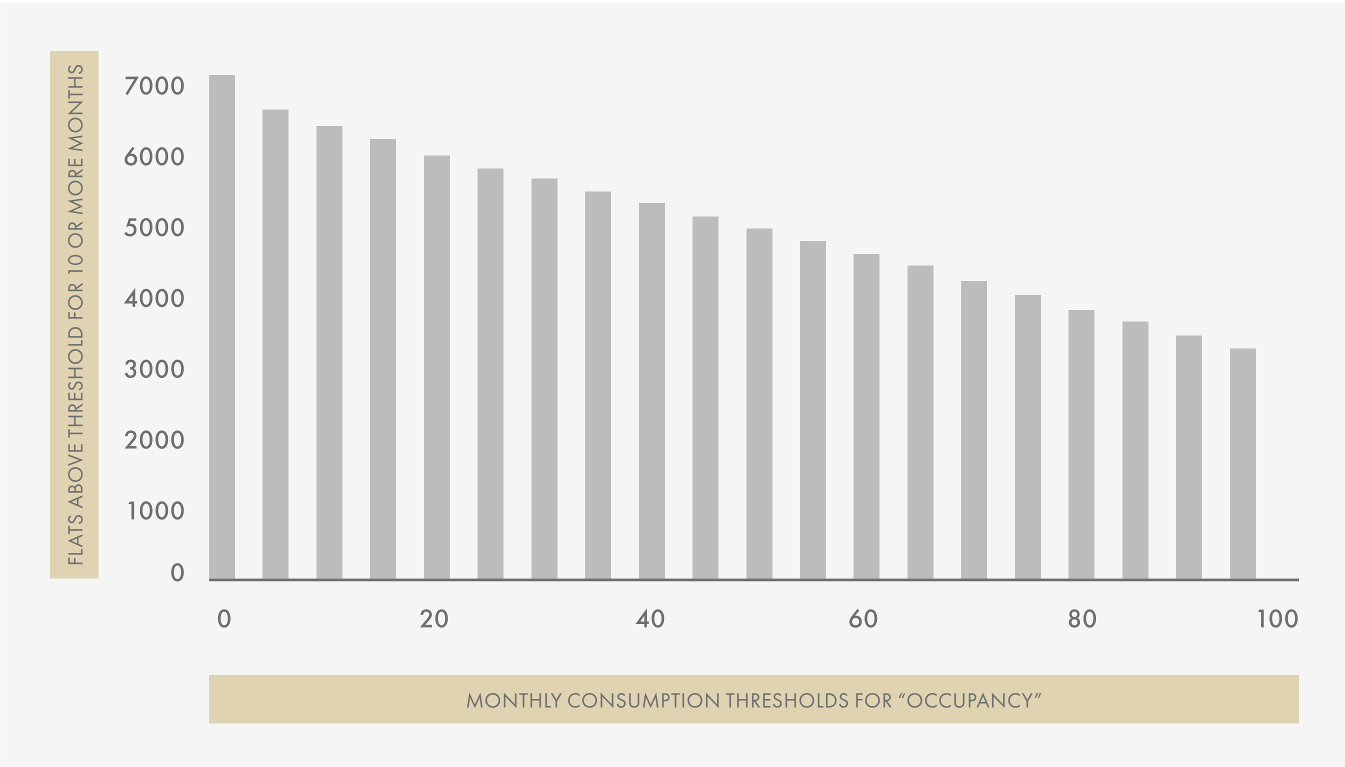


While the initial trends show weak correlations between EPI and other flat parameters, the gaps need to be fully understood to evaluate the design and operational impact on energy performance. Flat occupancy, flat RAC unit usage behaviour (given the 100% AC penetration in flats), load of non-cooling appliances and load from building common areas all confound what can be precisely understood from the raw monthly electricity consumption data.

Minimum energy use threshold

While this study excludes flats with minimum energy use below 50kWh/month, the number of flats excluded suggests that a large percentage of flats are occupied by few people, partially occupied and/or occupied with limited continuous appliance and energy use. As a result, this minimum floor cut-off could artificially limit the useable data for correlating EPI. However, there is no clear threshold at which flats are definitely unoccupied; the number of flats with a minimum threshold monthly energy consumption increases nearly linearly with the threshold value. This behaviour needs to be explored with direct survey and measurement using installed meters. Direct measurement can also help understand AC use patterns, including set point and time of use, time-of-day peak load, and monthly and yearly average performance.

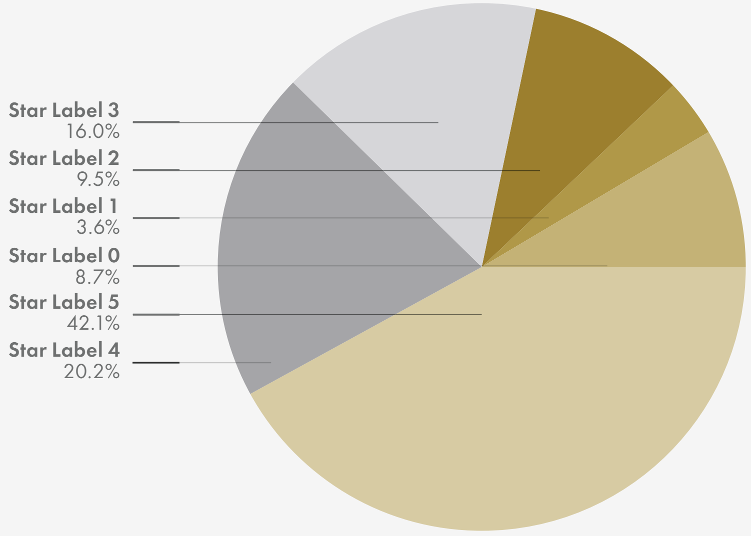
EXHIBIT 2.11 **NUMBER OF FLATS INCLUDED UNDER DIFFERENT OCCUPANCY MINIMUM THRESHOLDS**



Comparison with BEE

An initial distribution of the consumption-based EPIs of occupied and full set of flats can be mapped to the EPI values in BEE's residential building star labelling system. BEE's labelling system does not include non-cooling appliances (such as refrigerators and washing machines), so the 7 kWh/m²/year reduction for non-cooling appliances at the start of this paper is maintained for this comparison.

EXHIBIT 2.12 **BEE STAR LABEL DISTRIBUTION OF FLATS IN PALAVA**



More than half the flats fall under the 4- and 5-star category thresholds of 39 and 30kWh/m²/year, respectively, while 8.7% fall below the star labelling maximum EPI of 64kWh/m²/year. Notably, these EPI values do not necessarily reflect how these buildings would be rated under the star labelling programme, as BEE's labelling is based on theoretical, modelled energy performance. As found in the GBPN baseline study, simulated results are likely to show higher EPIs due to different thermal comfort expectations from residents than those assumed for comfortable conditions in the model. The average EPI of 34kWh/m²/year is 47% lower than the GRIHA standard benchmark of 70kWh/m²/year for residential buildings in hot and humid climates. These EPI values are also much lower than global benchmarks. Indian buildings already have a far lower energy footprint than the global average EPI of 152kWh/m²/year (all buildings).

CONCLUSION

The next steps in this study include conducting a comprehensive surveys, which are underway, to understand occupancy and behavioural patterns in the data, as identified above, studying second order correlations among EPI, design factors, weather data, local landscape, etc., and relating the household energy data to per capita energy consumption and household energy cost. While the design factors identified in this study only show weak correlations with EPI, there may be stronger correlations within subsets of the flats that additional study can identify. This ongoing study of energy consumption will continue to inform efficiency measures and experiments within the Accelerator and Palava. As stated initially, the RMI report shows that the trajectories of grid energy demand and emissions from the buildings sector can be different from the BAU — even with continued growth in RAC penetration and active cooling access between today and 2050 — largely driven by new construction.

Monitoring the energy use in developments like Palava and creating frameworks for rating and evaluating the comprehensive sustainability of residential buildings such as LEED, IGBC and GRIHA, in addition to BEE's EPI-based labelling programme, are important steps in connecting market value to building energy performance in India. Until now, granular building energy performance data had limited availability due to relatively low electricity use per household and inadequate infrastructure for collecting and using this data. However, with increasing RAC penetration and electric appliance use in residential buildings, greater monitoring can be part of a positively reinforcing feedback loop. Energy labelling and performance standards can be updated and strengthened by real performance data, and, in turn, create more value for data-driven performance and energy efficiency improvements.

Our existing assumptions are that emissions and energy use will continue to increase with improving GDP and thermal comfort access in India. However, energy use and performance data can continue to inform how we design our buildings and couple building design with increased renewable penetration, smart grid interactivity and better neighbourhood and city design such that we continue to improve living conditions and thermal comfort while maintaining low energy consumption averages. The sector requires that more of this data be collected, studied and shared for data-based decision-making to enable a growth path decoupled from carbon emissions.

ACTION PATHWAYS

The initial data collection and analysis has helped inform continued steps for understanding of energy consumption within Palava as well as for interventions and broader engagement.

1. Additional data collection and analysis:

As the analysis above points out, there are several relationships within the existing data that need to be investigated to understand the baseline energy consumption and factors that influence flat and building energy use. This includes of the following:

- Investigation of energy use outliers with extremely high or extremely low monthly energy consumption and EPI, to understand the data validity
- Investigation of the biases introduced by number of occupants per flat or per bedroom
- Improved approximation of flat occupancy energy use thresholds and non-cooling loads within each flat
- Investigation of EPI relationship to AC EER within each flat
- Determination of combinations of design factors (such as orientation, flat type) that may lead to specific EPI outcomes

Some of these objectives can be researched using the existing monthly energy data and external data sources such as local weather data. Information about occupancy, non-cooling loads, and cooling appliance behaviour would require direct engagement with residents to understand. This would include number of occupants and demographics of residents, refrigerator/washing machine/other appliance rated load and use, and AC use timings and typically set points. Data may be collected through surveys, meetings, metering of some homes or a combination of these methods. Direct measurement can also help to understand AC use patterns, including set point and time of use, as well as time-of-day peak load, in addition to monthly and yearly averaged performance.

2. Use the baseline data to test further energy efficiency retrofits

Using the baseline energy consumption data, Lodha can evaluate the efficacy of energy efficiency retrofits at the individual flat level, as well as aggregate impacts of energy efficiency retrofits on larger groups of flats at the building or block level. These retrofits can include appliance upgrades (BLDC fans and high efficiency RACs) as well as envelope efficiency improvements (windows, shading, reflective paints, ventilation, etc). Some of these technologies are already being tested in Palava; the baseline energy data allows for a basis for comparison across buildings tested with different interventions.

3. Use the baseline data to test behavioural interventions

After establishing a baseline set of data around household energy usage patterns and behaviours, Lodha can test the effect of various behavioural change interventions, which can reduce household energy use by 1–3%.[14]

Possible behavioural interventions based on home energy reports:

i. Create a way for renters or owners to interact with their own electricity consumption data against baselines for other homes of their size/type/building to understand cost and energy saving potential. This would require engaging with residents to understand best metrics to use and most engaging delivery of information

ii. Deliver data to a subset of residents to gain feedback on follow up questions residents have

iii. Measure energy use changes to evaluate impact against baseline of residents who were not provided this data

Additional interventions might include individual or block level challenges or incentives for energy savings across different parts of the Lodha development. A similar set of steps would follow:

i. Determine the baseline energy use at the block level

ii. Design a challenge or game that incentivising reduced energy usage or cost savings

iii. Deliver data to a subset of residents to gain feedback on follow up questions residents have

iv. Measure energy use changes to evaluate impact against baseline of residents outside of this challenge

4. Broader discussion

The baseline data can also inform how the Accelerator participates in a broader discussion around energy labelling standards and building energy data transparency. Some steps can include:

- Perform a detailed comparison of measured energy data to modelled data using the methodology recommended by BEE to evaluate EPI of Palava buildings as they compare to BEEs energy standards for residential buildings

- Share comparative information with BEE to add to the discourse around residential energy labelling and star rating thresholds

- Determine the steps that the Accelerator can take to inform a broader energy data collection framework for residential buildings. The Accelerator can share lessons learned, and suggest a framework to other entities in the real estate space for energy data transparency

- Participate in a broader study and discussion about the implications of energy data and the benchmarks found in Palava on India’s building sector contribution towards the NDCs

APPENDIX: ADDITIONAL CORRELATION EXHIBITS

EXHIBIT 2.13 **CORRELATION OF EPI WITH BEDROOM COUNT**

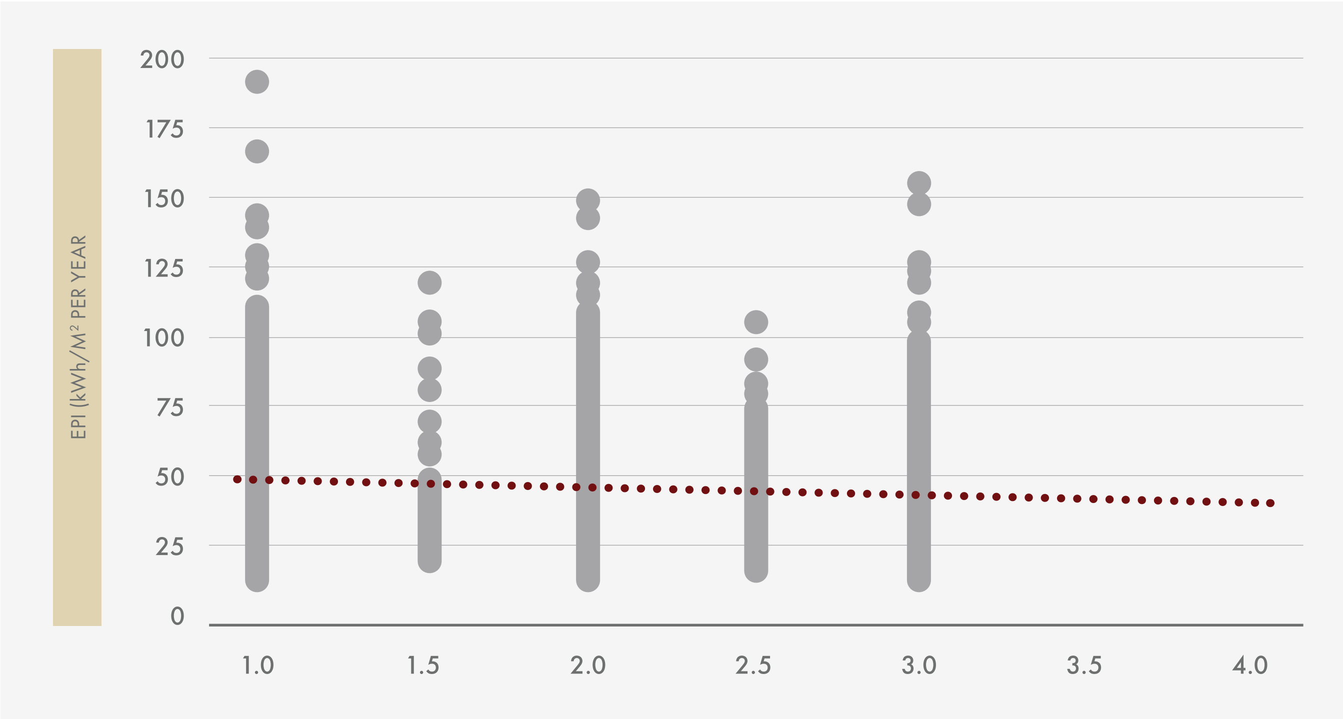


EXHIBIT 2.14 **CORRELATION OF EPI WITH FLOOR NUMBER**

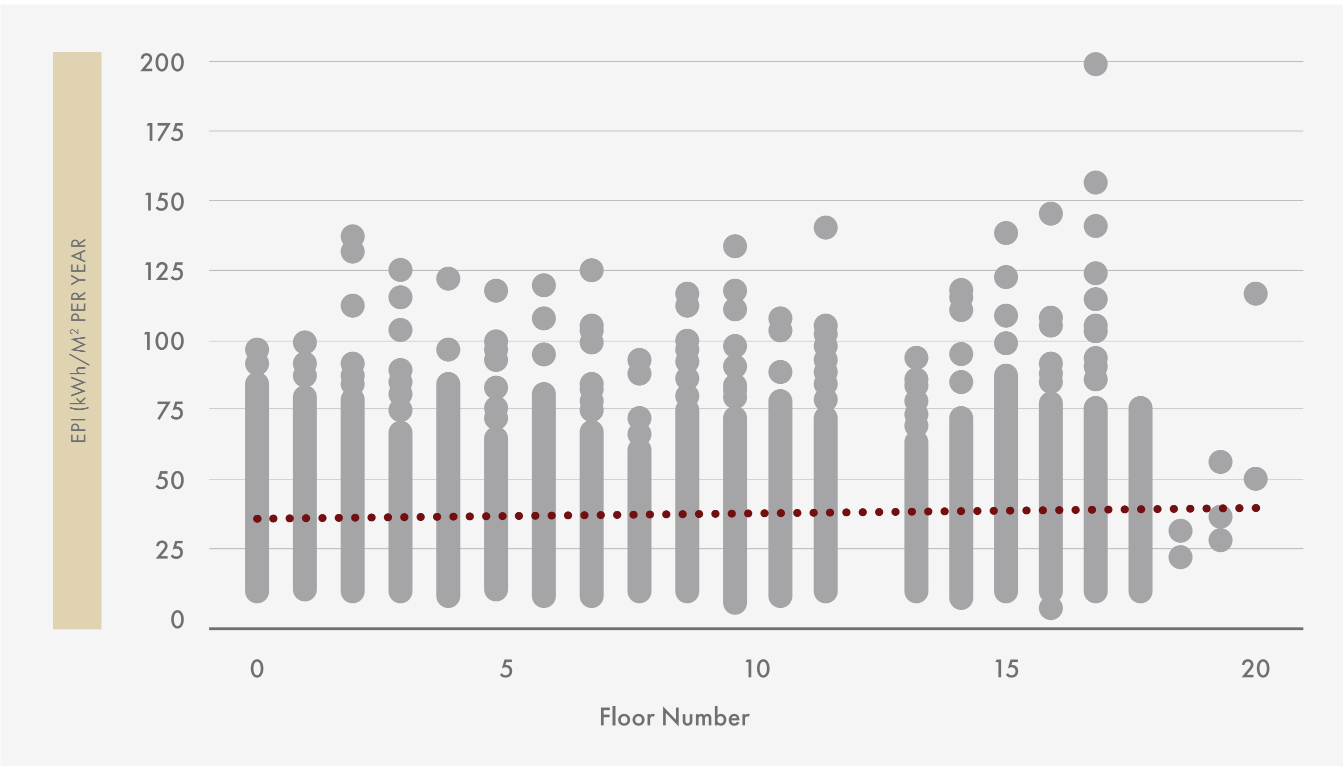


TABLE 2.1 **CORRELATION OF FLAT ORIENTATION WITH EPI**

		EPI [KWH/M²/YEAR]				
PRIMARY FLAT ORIENTATION	**NUMBER OF FLATS**	**MEAN**	**STANDARD DEVIATION**	**MIN**	**MEDIAN**	**MAX**
EAST	610	42.8	17.1	14.0	30.0	40.0
NORTH	1,891	45.2	19.9	12.0	31.0	41.0
SOUTH	1,965	44.6	18.5	12.0	32.0	41.0
WEST	571	44.0	18.3	17.0	30.0	40.0
TOTAL	**5,037**					

TABLE 2.2 **CORRELATION OF EPI WITH PRIMARY BEDROOM AC EER**

		EPI [KWH/M²/YEAR]		
PRIMARY BEDROOM AC EER	**NUMBER OF ACs**	**MEAN**	**STD**	**MEDIAN**
3	36	48.1	21.3	45.5
3.29	4,024	43.2	17.9	40.0
3.6	459	49.5	20.5	45.0
5.24	518	50.4	22.6	46.0
TOTAL	5,037			

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CHAPTER 3

Urban Heat Mapping: Case Study of Palava City

CONTEXT

Rising temperature is globally identified as a growing threat to humans. The continuous increase in greenhouse gas emissions from human activities has led to significant warming of the Earth's climate. Extreme heat, exacerbated by climate change, is poised to significantly disrupt various industries, from tourism and construction to manufacturing and insurance, while hampering human productivity and well-being. Challenges faced by these sectors include decreased productivity, infrastructure damage, increased operational costs and high insurance premiums, necessitating urgent adaptation measures.[1]

Amid the mounting concern over the global rise in temperatures, the phenomenon known as urban heat islands (UHIs) is becoming increasingly prevalent. This phenomenon is characterised by cities and urban areas recording higher temperatures than their surrounding regions. UHIs are a result of land surface modifications, increased human activity and prevalence of heat-absorbing materials in urban settings. Several factors contribute to the formation of these heat islands, including extensive concrete and asphalt surfaces, reduced vegetation and high energy consumption in cities that trap and retain heat. This effect is particularly notable during heatwaves and other extreme weather events. The warming in these areas is a combined result of the urban heat island effect (UHIE), driven by the physical attributes of cities, and the heat generated by human activities within these urban spaces. This dual effect intensifies the thermal balance of a location, leading to a more pronounced UHI phenomenon.

The UHIE significantly impacts electricity demand and urban infrastructure. The rising temperatures in urban areas increase the demand for cooling systems such as air conditioners and fans. Furthermore, elevated energy consumption strains local electricity grids, especially during peak periods, potentially leading to power outages and compromising the reliability of the energy supply. In the Global South, where many countries are recording rapid urbanisation and population growth, the effects of UHIs are particularly pronounced.

As India is one of the most populous countries and located near the equator, it faces significant challenges due to heat stress and UHIs. In particular, urban areas experience amplified heat during heatwaves, posing serious health risks to the population. For instance, Maharashtra in western India is highly vulnerable to heat stress due to the dense nature of urban development. Its tier 1 and 2 cities have intense urbanisation and population density and bear the brunt of the UHIE.[2] As a result, cooling-related energy demand is expected to be exacerbated, further straining the electricity grid during extreme heat events. To develop and implement mitigation and adaptation measures, it is important to assess and understand temperature variations and impact of UHIs in different areas within a city. Heat mapping is a tool that helps assess the impact of urban heat.

HEAT MAPPING

Heat mapping is crucial in understanding and addressing the UHIE. Heat maps are graphical representations of the spatial distribution of temperatures across a city or particular urban area, highlighting the regions with the highest and lowest temperatures. It provides valuable insights into climate change patterns and regional variations in temperature and identifies areas with significant warming or cooling. The heat mapping exercise for any local location can help **(I) ideate** and identify areas of interventions, **(C) create** data repository and data-backed action pathways and **(E) enable** sub-national activities such as informed urban planning, suggesting public policy discourse and energy planning as depicted in Exhibit 3.1.

EXHIBIT 3.1 **IDEATE, CREATE AND ENABLE FRAMEWORK FOR URBAN HEAT RESILIENCE**

1	2	3	4	5
IDENTIFY HOT SPOTS	**CREATION OF DATA REPOSITORY**	**ENABLE ON-GROUND ACTIONS**	**ENABLE IMPROVED INFRASTRUCTURE PLANNING**	**ENABLE PUBLIC POLICY DISCOURSE**
Heat maps can help identify areas within a city that are significantly warmer than others. These hot spots often coincide with regions that have extensive concrete or asphalt surfaces and minimal vegetation.	Heat maps can act as data repository for the future cities to assess and understand the change in the weather pattern in the localised context spread across a period and analyse the impact of interventions.	The data from heat maps can guide on ground actions. For instance, city authorities can use this information to increase green spaces or improve building designs in hot spots to mitigate the urban heat island effect.	Heat maps can inform planning decisions, as areas with higher temperatures may have higher power outages, reduced infrastructure life. This information can help city authorities plan for peak heat periods.	Findings can then inform mitigation strategies for authorities to plan resources for interventions to protect vulnerable populations during heatwaves.
IDEATE	CREATE	ENABLE LOCAL & NATIONAL ACTIONS		

HEAT MAPPING FOR PALAVA UNDER THE ACCELERATOR

To establish the emission reduction pathways for Palava City being developed by Lodha, heat stress analysis through heat mapping was considered a key first step in identifying hot spots and creating a data repository. By assessing heat stress levels in different areas, developers can identify locations that are increasingly prone to heat stress or have few heat mitigating factors such as vegetation cover or proximity to water bodies. By understanding the local climate and heat stress patterns, developers can incorporate strategies such as proper insulation, natural ventilation, shading devices, cool roof materials, smart surfaces, nature-based solutions and efficient heating, ventilation and air-conditioning (HVAC) systems. This information can guide the selection of suitable sites for development, ensuring better thermal comfort for occupants and reducing potential health risks.

Furthermore, such analyses enable developers to optimise the built environment design to mitigate the effects of heat stress. These measures can enhance thermal comfort, reduce energy consumption, and improve the overall livability and desirability of the built environment. Results can also be used for marketing to attract environment-conscious customers and augment the perceived value of the development. Actionable insights from these maps can increase engagement with local stakeholders, including residents, communities and even public authorities.

This analysis specifically aims at creating a replicable blueprint by addressing the following goals:

- Develop a methodology for time-bound heat stress analysis to produce actionable insights for Lodha.
- Apply the developed approach to a part of Palava City and provide subsequent urban-cooling actions to further the local climatic conditions.
- Suggest additional next steps to bolster this methodology for it to be appropriate across various use cases.

OBJECTIVES

This activity focuses on the following:

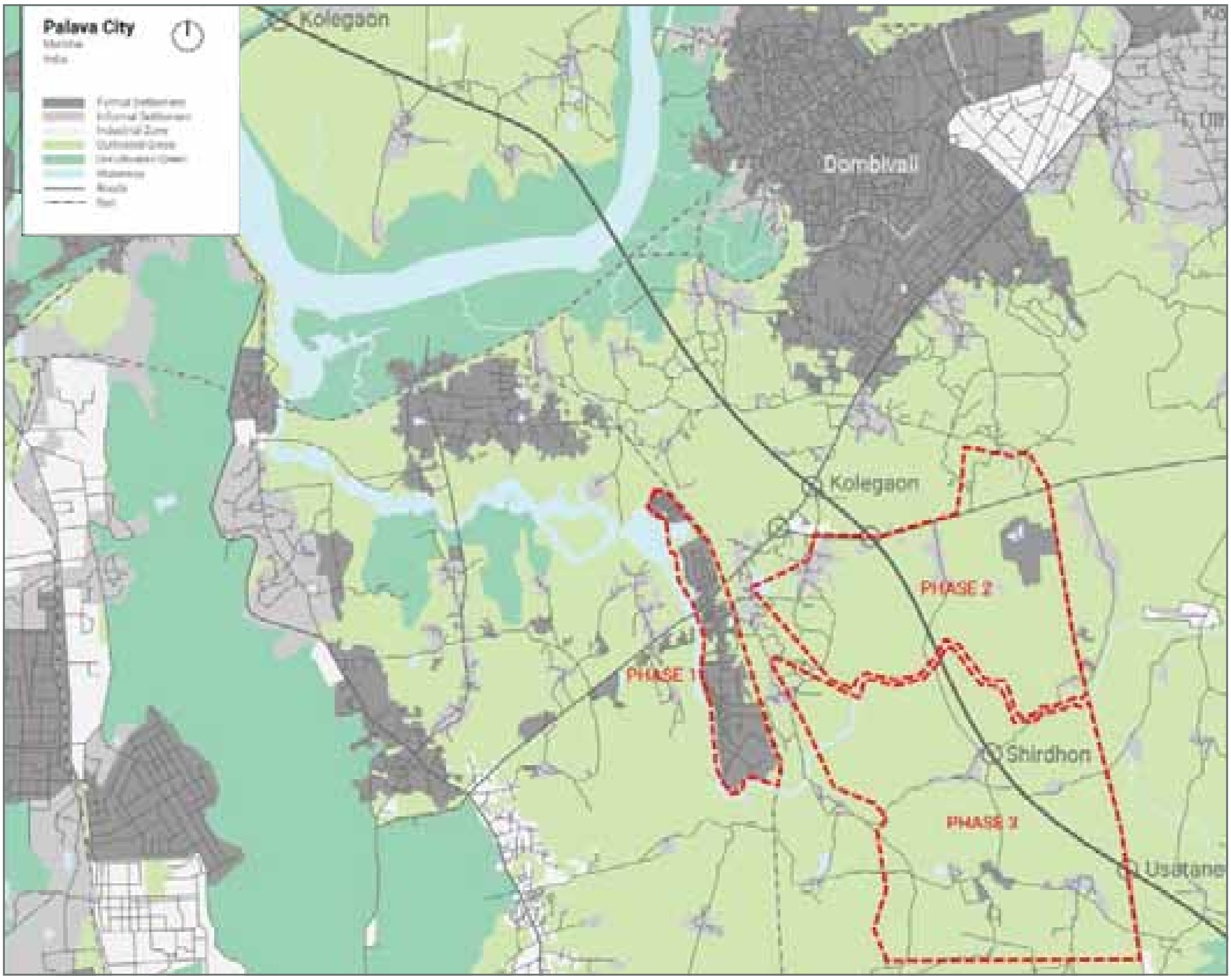
1. Presenting a methodology for heat stress mapping using satellite data.
2. Proposing additional heat stress mapping and monitoring frameworks.
3. Showing a high-level analysis of Palava City's Phase I.
    a. Comparative analysis of neighbouring areas
    b. Change of heat stress over time
    c. Felt-heat index and how to calculate it
4. Identifying how the Accelerator can institutionalise heat stress monitoring for different contextual needs.

OVERVIEW OF PALAVA CITY

Palava City is a smart city built by Lodha between Thane, Navi Mumbai and Kalyan, spread across 18 square kilometres of land and home to around 33,000 households. Divided into three phases, it is a mixed-use city that offers dedicated residential, commercial and recreational spaces along with healthcare, education and public transport. March to May is typically the hottest period of the year, followed by monsoon between June and September, post-monsoon autumn from October to November, and winter typically from December to February.

For this analysis, we focused on Phase I, as shown in Exhibit 3.2, exclusively as it is the longest standing site (since 2009) and has the highest occupancy rate. This allowed us to glean insights on how construction, human traffic and economic activity might affect local heat stress.

EXHIBIT 3.2 **REPRESENTATION OF PALAVA'S BOUNDARIES**



Our approach and methodology

For this exercise, we deployed a twofold approach of employing satellite data to gauge heat stress using Landsat data to model the land surface temperature and on-ground monitoring through the three stations in Palava City. This balanced the need for rigour with leveraging existing resources and unearthing actionable insights in a timebound manner. An alternative model developed by CARBSE provides significant flexibility for in-depth analysis, specifically for measuring the UHIE, and is identified as a possible alternative in case that level of analysis is required in the future.

SATELLITE REMOTE SENSING THROUGH LST

Land surface temperature (LST) — the radiative temperature of the land derived from thermal infrared radiation that the Earth's surface emits — was selected as the primary indicator. LST is essentially a measure of 'how hot Earth's surface would feel to the touch in a particular location.' In 2016, LST was listed as one of the essential climate variables (ECVs) by the Global Climate Observation System (GCOS) of the World Meteorological Organization (WMO). Various sources and methods are typically deployed based on contextual requirements to measure and estimate heat stress using satellite data.

LST data can be obtained from multiple sources such as moderate resolution imaging spectroradiometer (MODIS), Sentinel and Landsat instruments. A model developed by Ermida et al (2020),[3] which primarily relies on Landsat data, was used for this exercise due to the following:

1

Long-Term Data Continuity

Landsat has a consistent and continuous data record spanning several decades. This long-term data continuity allows for the analysis of LST changes and trends over time, providing valuable insights into climate patterns, land surface dynamics and UHIE.

2

Moderate–High Spatial Resolution

Landsat provides moderate to high spatial resolution imagery, typically at a 30-metre resolution (for Landsat 8). This resolution is well-suited for a detailed local LST analysis, facilitating the study of urban areas, small-scale land use patterns and localised temperature variations. Ermida et al's model uses resampling techniques to maintain the resolution at 30mx30m pixels.

3

Thermal Infrared Bands

Landsat sensors have dedicated thermal infrared bands designed to measure thermal radiation emitted by the Earth's surface. These thermal bands (e.g., Landsat 8's Thermal Infrared Sensor) provide specific information for estimating LST.

4

Freely Available Data

Landsat data is freely accessible to the public through the United States Geological Survey (USGS) archives (available here), facilitating widespread usage and encouraged scientific collaboration worldwide.

5

Calibration and Validation

Landsat data undergoes rigorous calibration and validation processes to ensure accuracy and reliability. The calibration procedures minimise atmospheric effects and sensor-related biases, resulting in more precise LST estimation.

6

Ancillary Data Integration

Landsat imagery can be easily integrated with other geospatial datasets such as land cover maps, digital elevation models and meteorological data. This integration enables researchers to examine the relation between LST and various environmental factors, enhancing the understanding of temperature dynamics.

7

Global Coverage and Revisit Frequency

The Landsat programme ensures global coverage with a regular revisit frequency. Landsat satellites cover the entire Earth's surface approximately every 16 days (for Landsat 8), enabling consistent monitoring of LST changes and capturing temporal variations.

Certain trade-offs are implied here, including low resolution (compared with on-ground monitoring), obscured view of skies for satellites, low frequency of imagery (Landsat 7 and 8 satellites together collect images every eight days) and mismatch of LST data with what heat feels like to humans because of additional factors such as humidity and wind speed.

ON-GROUND MONITORING

Located in the three phases of Palava City as shown in Exhibit 3.3, the three monitoring stations deploy measures temperature, humidity, luminosity of the sun, air quality metrics and wind character.

EXHIBIT 3.3 **LOCATION SITES FOR THE THREE ON-GROUND MONITORING STATIONS**

Hourly data from the monitoring stations for 27 March to 27 May 2023 was made available. Two felt temperature indices — the Canadian Humidex and US National Weather Service Heat Index — were then used and categorised according to severity thresholds. The India Meteorological Department (IMD) is currently developing its own index specifically built for the South Asian context; this will likely be ready by 2024 and provide a more accurate understanding of heat stress using data from existing databases linked to the on-ground monitoring stations in Palava City.

Limitations

- Satellite data often has a constrained spatial resolution, and certain inconsistencies may arise between different satellites.

- Data availability and temporal coverage are limited, with a 16-day cycle per active satellite.

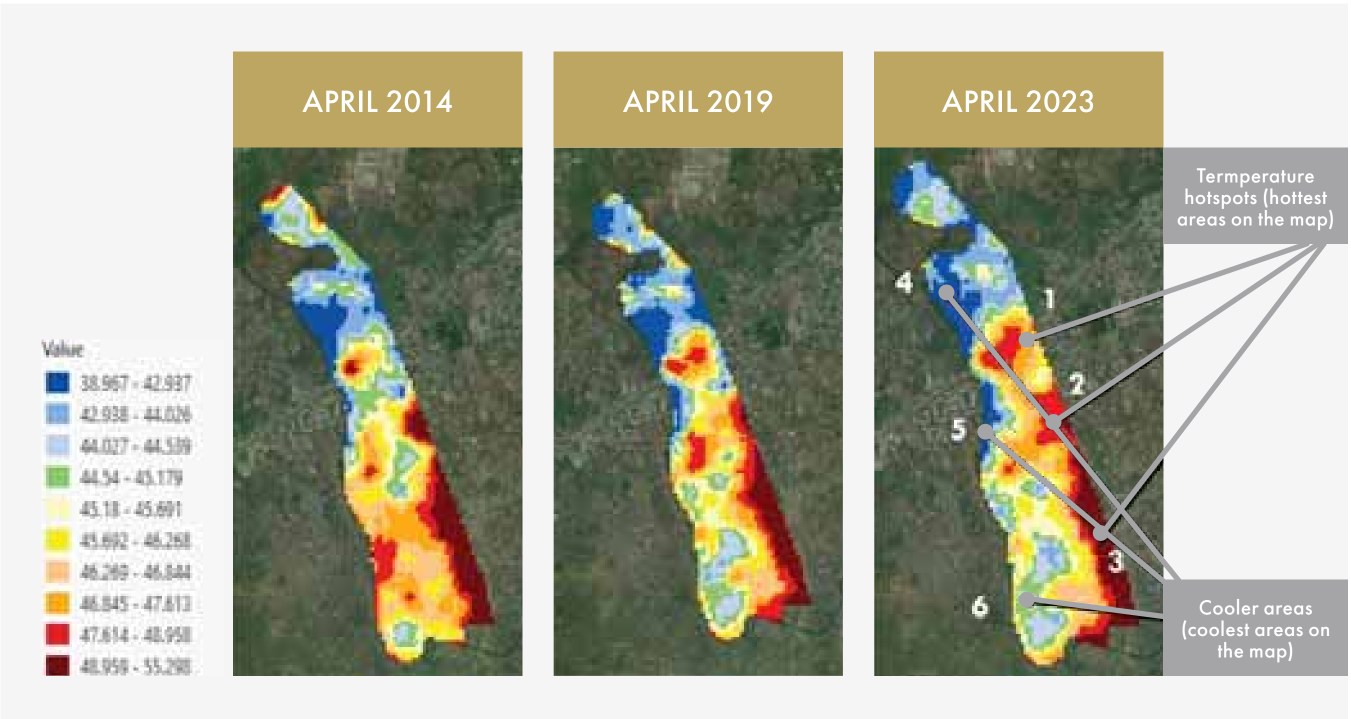
- The representation of ground-level air temperature experienced by humans might be inaccurate.
- The data may not capture intra-building variations and microclimatic effects, including aspects such as shading.
- While ground monitoring systems offer superior accuracy, they do not provide spatial information. For instance, having one station per phase can obscure the temperature

ANALYSIS — PALAVA CITY

Deep dive analysis of Palava Phase I

Diving deep into Palava Phase I, LST maps were created to snapshot temperature distribution for April — the hottest time of the year according to Landsat averages. A few emerging hot spots are clearly visible, as are areas that have cooled dramatically. These have been marked and numbered as in Exhibits 3.4 and 3.5

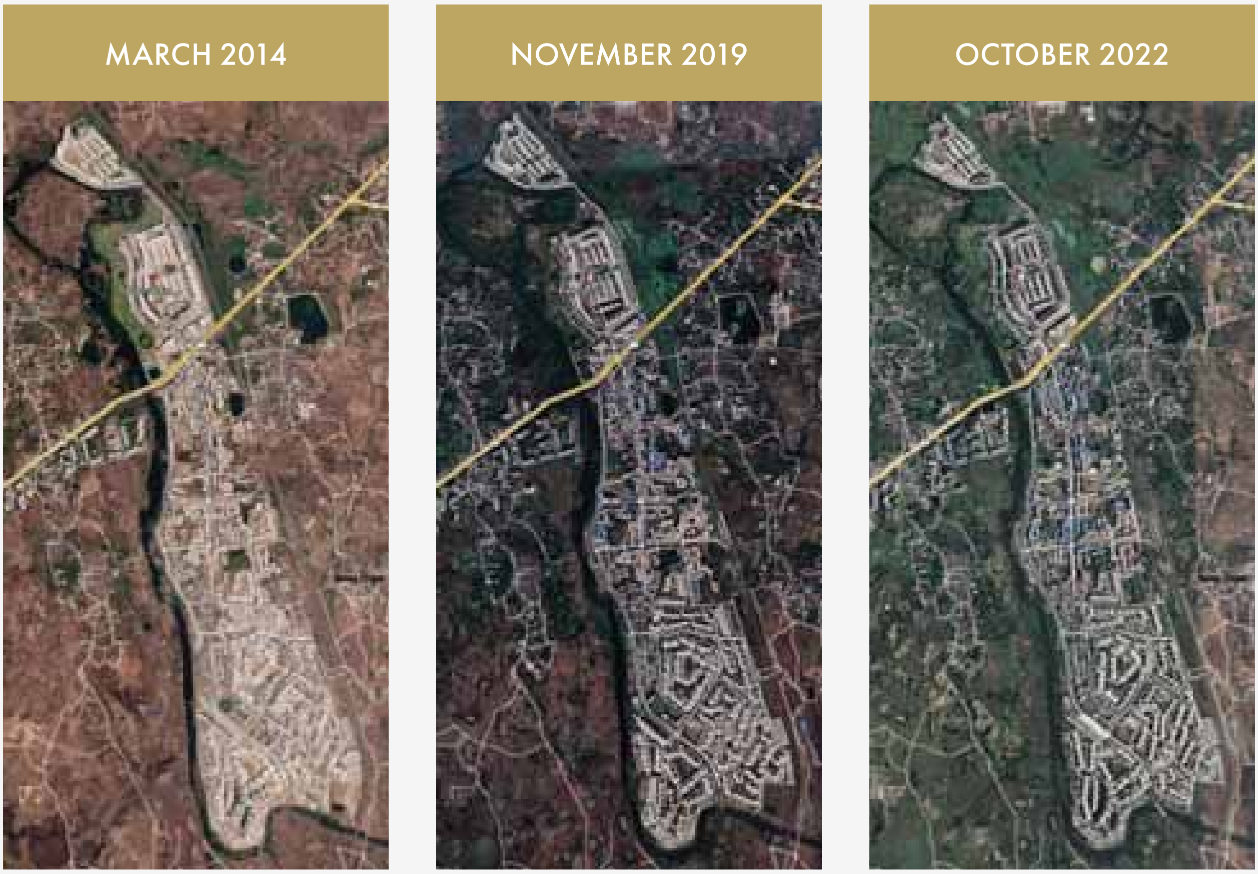
EXHIBIT 3.4 **LST MAPS FOR APRIL 2014, 2019, 2023**



Source: Landsat 7 and 8 Imagery

To better explore the possible causes of the development of these temperature anomalies, we visually compared LST maps with Google Earth images (as a proxy for land use).

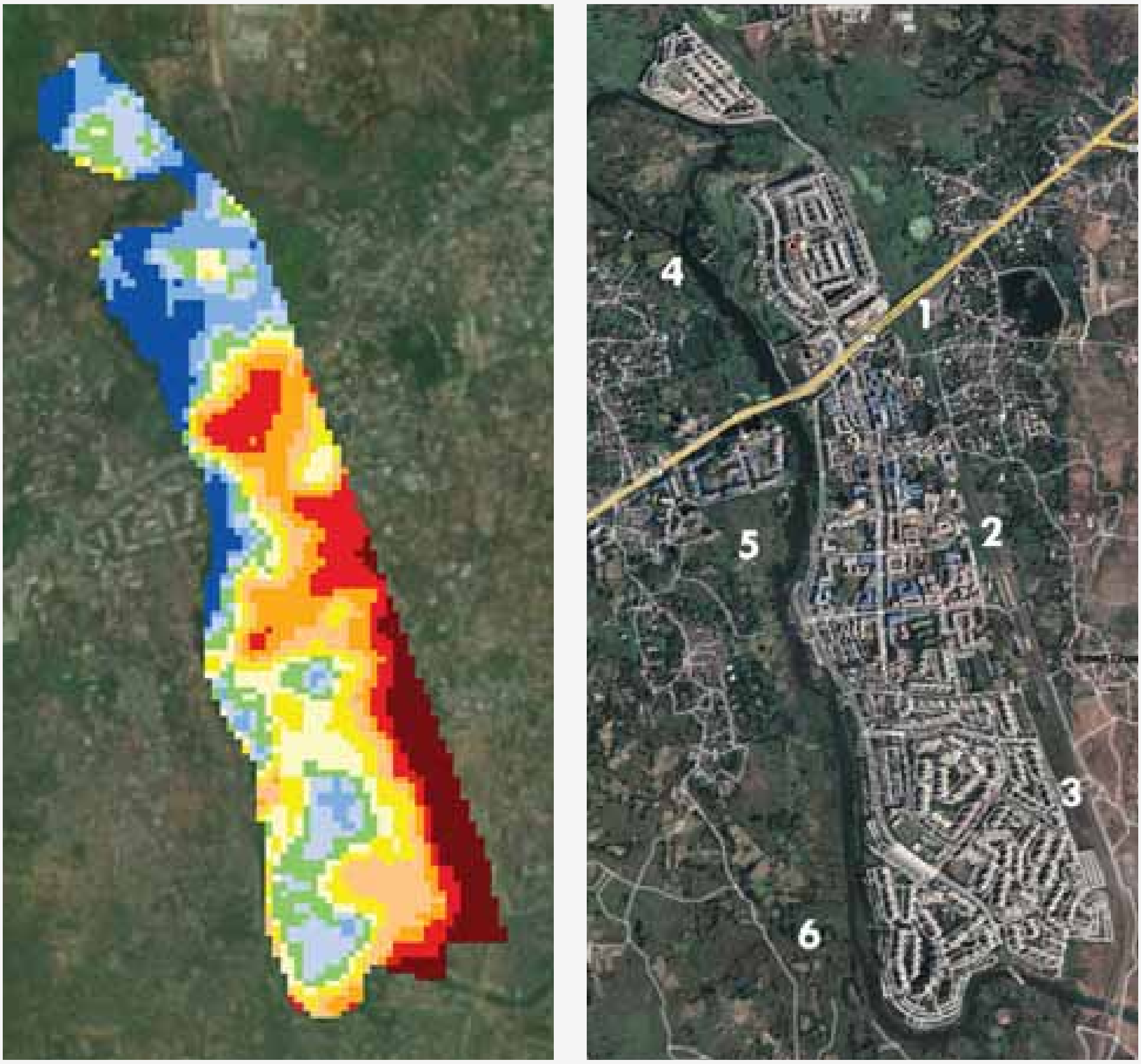
EXHIBIT 3.5 **GOOGLE EARTH IMAGES OF DEVELOPMENT IN PALAVA**



Source: Google Earth

A comparative analysis for 2023 is presented below. This visual correlation of hot spots with unique land-use patterns provides an intuitive check for the origins of temperature anomalies. An initial analysis of the hot spots is also presented in Exhibits 3.6 and 3.7.

EXHIBIT 3.6 **SIDE-BY-SIDE COMPARISON OF LST AND SATELLITE IMAGES OF PALAVA PHASE I (APRIL 2023)**



Source: Google Earth

EXHIBIT 3.7 **ANALYSIS OF HOT SPOTS**

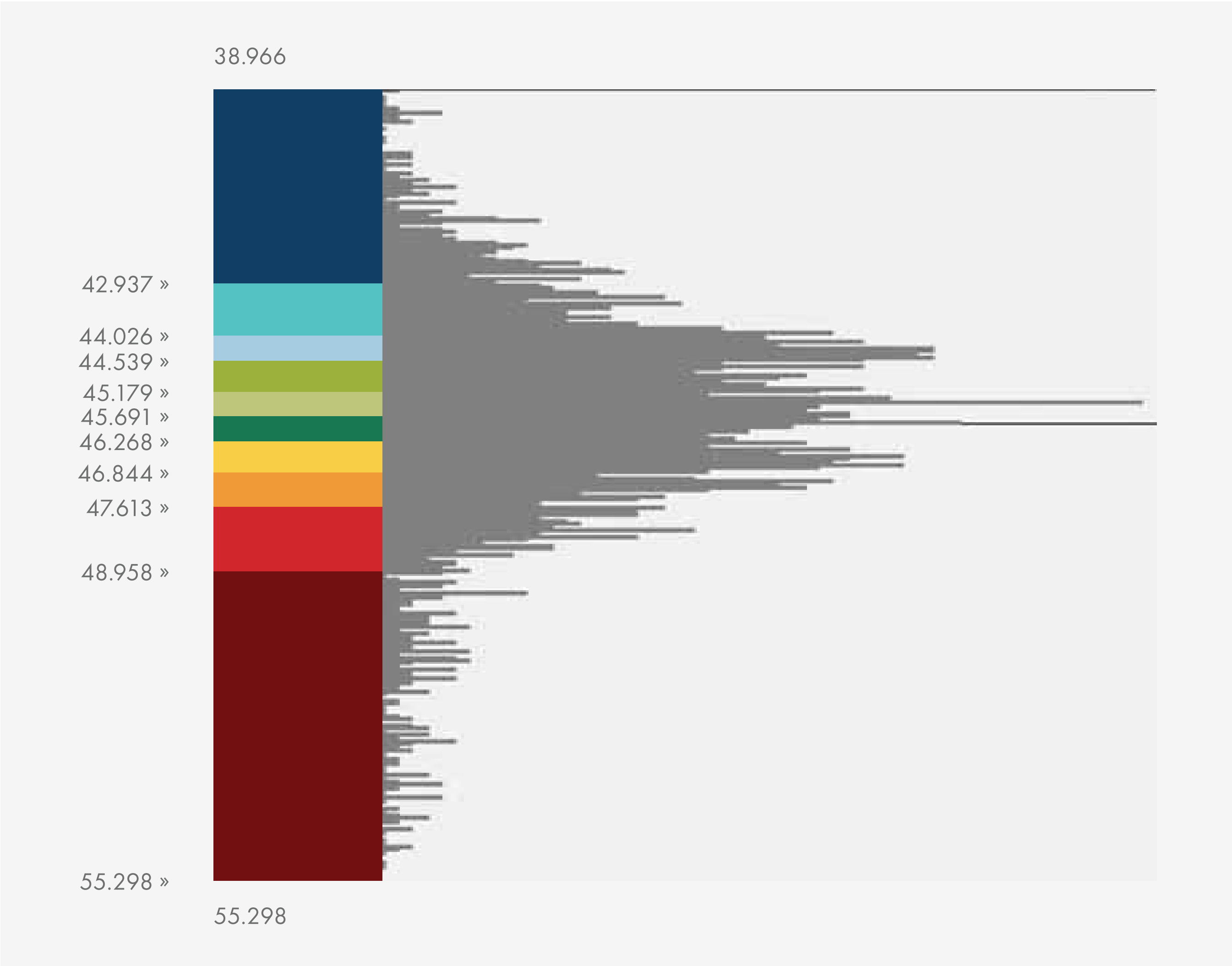
SPOT #	CATEGORY	POSSIBLE CAUSE(S)
1	Hot, heating up	Construction and increased vehicular traffic on State Highway 76 (SH76)
2	Hot	Densely built-up area — extensive study required
3	Hot	**Note that the area under spot 3 is not entirely within the boundaries of Palava City. Some part represents an adjacent railway station, which cannot be displayed due to the limitations of satellite imaging**. Extensive study is required to assess the impact of the urban heat radiated from the railway station.
4	Cool	Elevation + wind, nearby water body, green space
5	Cool, cooling down	Growing green space, nearby water body, completion of construction
6	Cool, cooling down	Growing green space, nearby water body, completion of construction
7	Cool, cooling down	Growing green space, nearby water body, completion of construction — not as cool as 4, 5, 6

For a more rigorous and technically sound approach to identify the causes of heat stress, it is advisable to use Land Use Land Cover (LULC) or Normalised Difference Built-up Index (NDBI) to analyse satellite data representing land use.

Phase 1— Palava LST distribution in April 2023

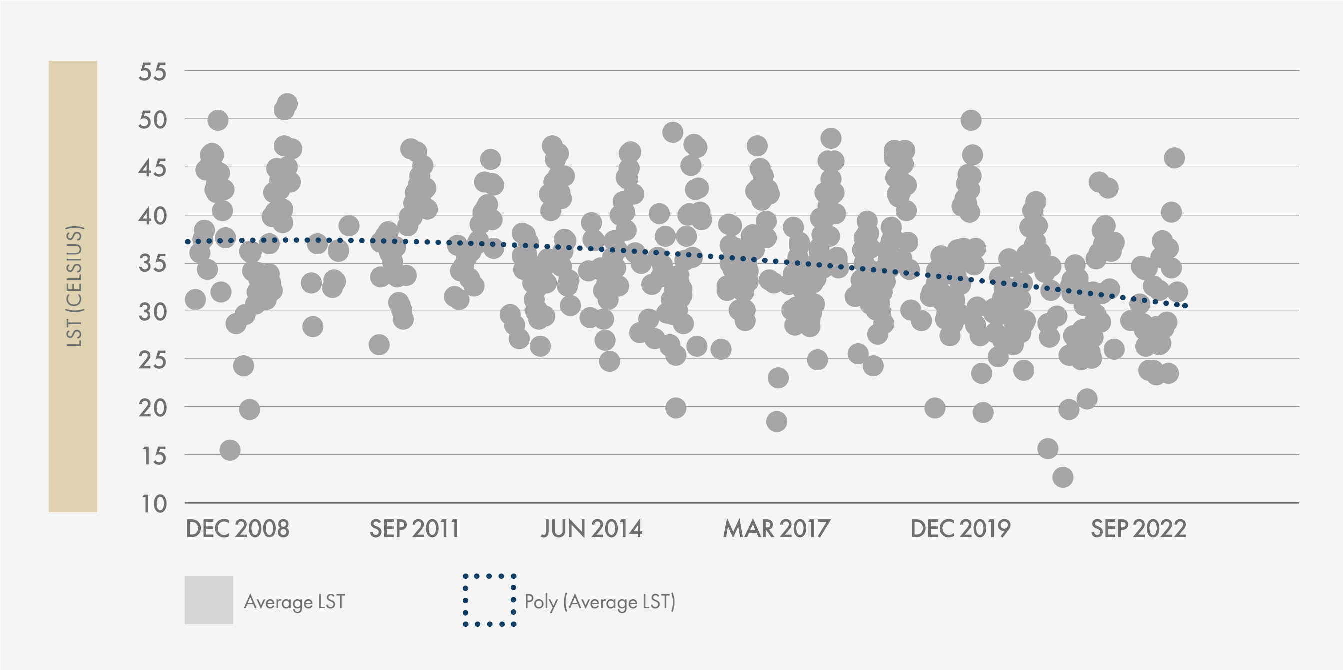
As shown in Exhibit 3.8, the minimum LST in Palava Phase I was around 38.97°C and the maximum was 55.30°C. The mean LST was 45.89°C with a standard deviation of 2.53°C, as shown in Exhibit 3.8.

EXHIBIT 3.8 **TEMPERATURE BANDS (Y AXIS) AND SURFACE AREA THEY REPRESENT (X-AXIS) IN PALAVA PHASE I (APRIL 2023)**



Interestingly, Phase I's average temperature over the past 15 years has steadily reduced to nearly 7°C lower than its initial level in 2009. The LST drop from around 37°C to nearly 30°C is visualised as a geometric trend line in Exhibit 3.9.

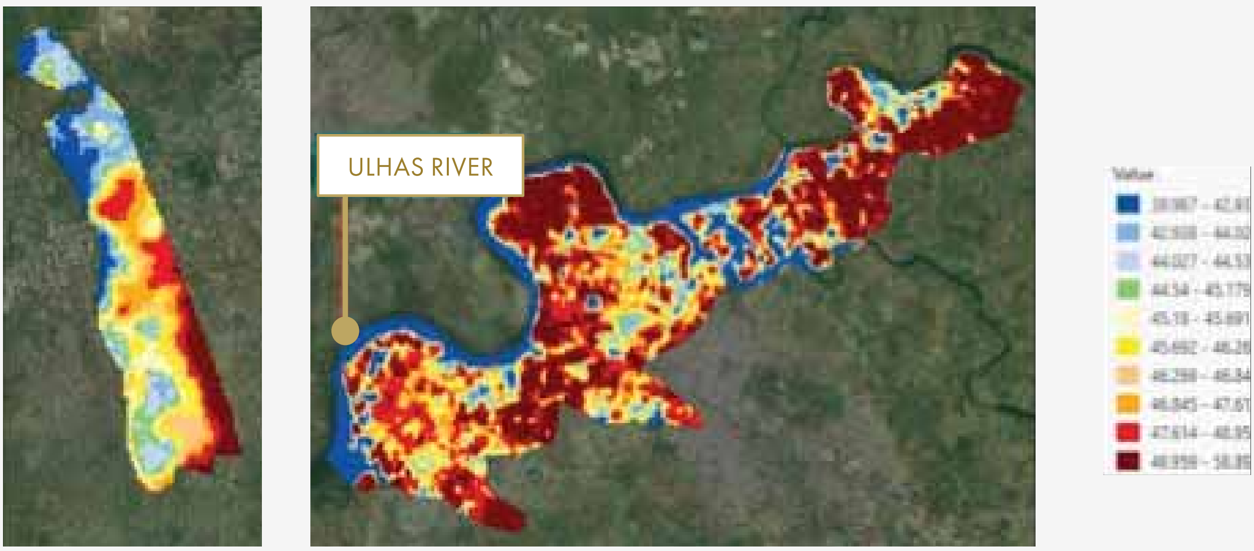
EXHIBIT 3.9 **AVERAGE LST READINGS FOR PALAVA PHASE I SINCE 1 JANUARY 2009**



Comparison of Palava Phase I with Kalyan–Dombivali and Mumbai

Phase I has a higher minimum temperature probably attributable to Dombivali's proximity to river systems. However, the maximum temperature is much higher in Kalyan–Dombivali due to more dense urban development as presented in Exhibit 3.10.

EXHIBIT 3.10 **DETAILS OF LST IN PALAVA PHASE I AND KALYAN–DOMBIVALI IN APRIL 2023**



The following Exhibit 3.11 informs on the minimum, maximum and mean comparative of LSTs.

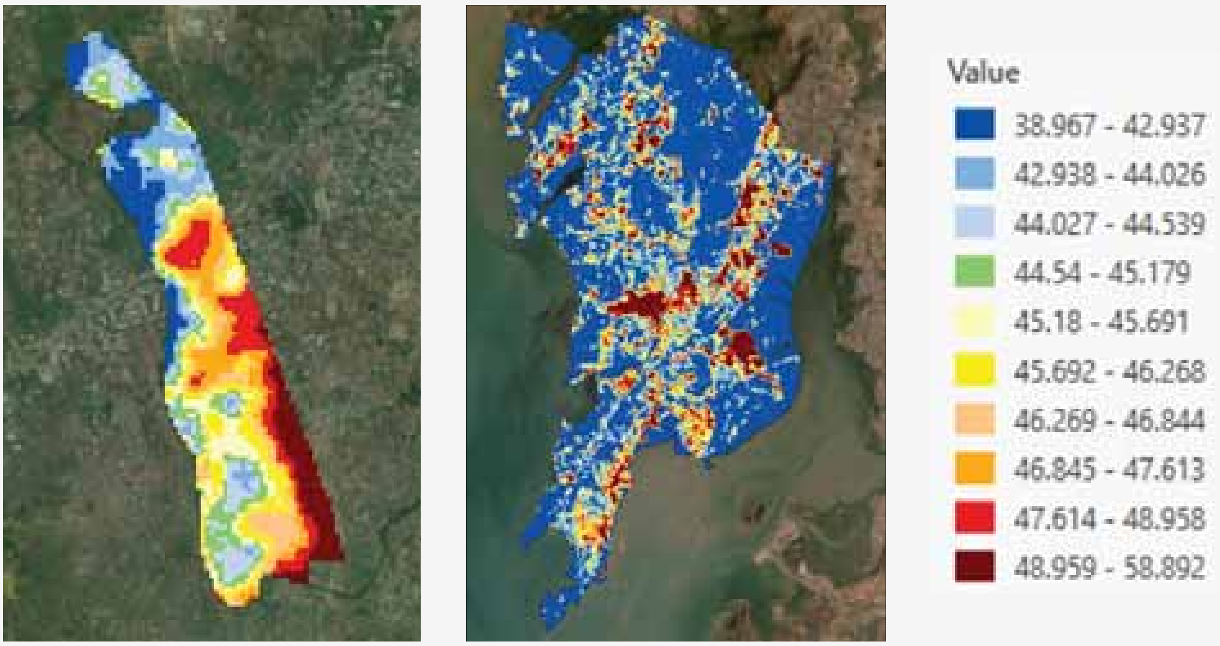
STATISTIC	PALAVA PHASE I (°C)	KALYAN–DOMBIVALI (°C)
Minimum LST	38.97	34.06
Maximum LST	55.30	58.89
Mean LST	45.89	**47.02**
Standard Deviation	2.53	4.05

Notwithstanding, the maximum temperature in Palava Phase I (55.3°C) is nearly 3.5°C cooler and average temperatures are 1.2°C lower. Notably, Palava Phase I's standard deviation of only 2.5°C means that LST does not vary as much within the area (compared with that of Kalyan–Dombivali, which is almost double).

Comparison of Palava Phase I with Mumbai

Mumbai has a considerable blue cover and is 3°C cooler than Palava Phase I on average. However, its maximum temperature is significantly higher (+2°C) than that of Phase I due to dense urbanisation and lack of urban cooling solutions.

EXHIBIT 3.11 **COMPARISON OF PALAVA AND MUMBAI**

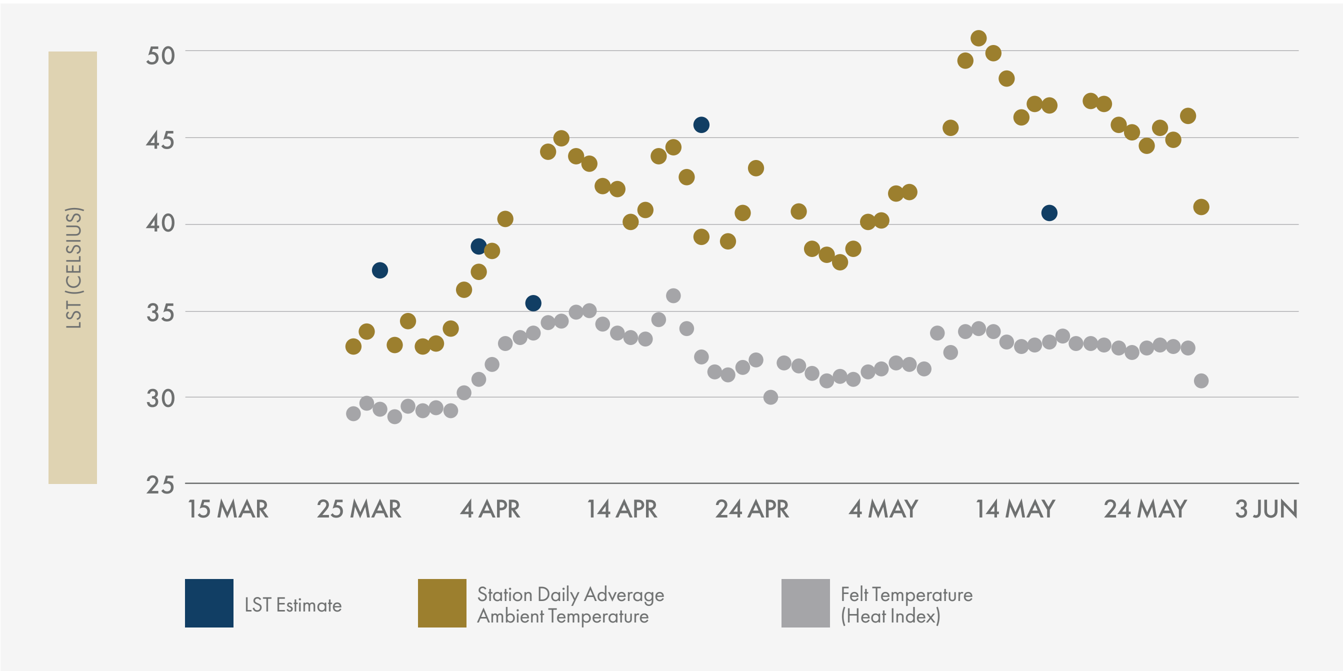


Interventions proposed in Palava City must therefore focus on medium temperature reduction over large swathes of land vis-à-vis Mumbai's concentration of extreme temperatures in small pockets.

Ambient and wet bulb temperatures from on-ground monitoring stations

Satellite data is best suited to glean high-level insights and actionable next steps for an extensive study, while on-ground monitoring provides a clear and updated picture of heat stress and thermal comfort. As noted in Exhibit 3.12, the frequency of available data is much higher than LST estimates.

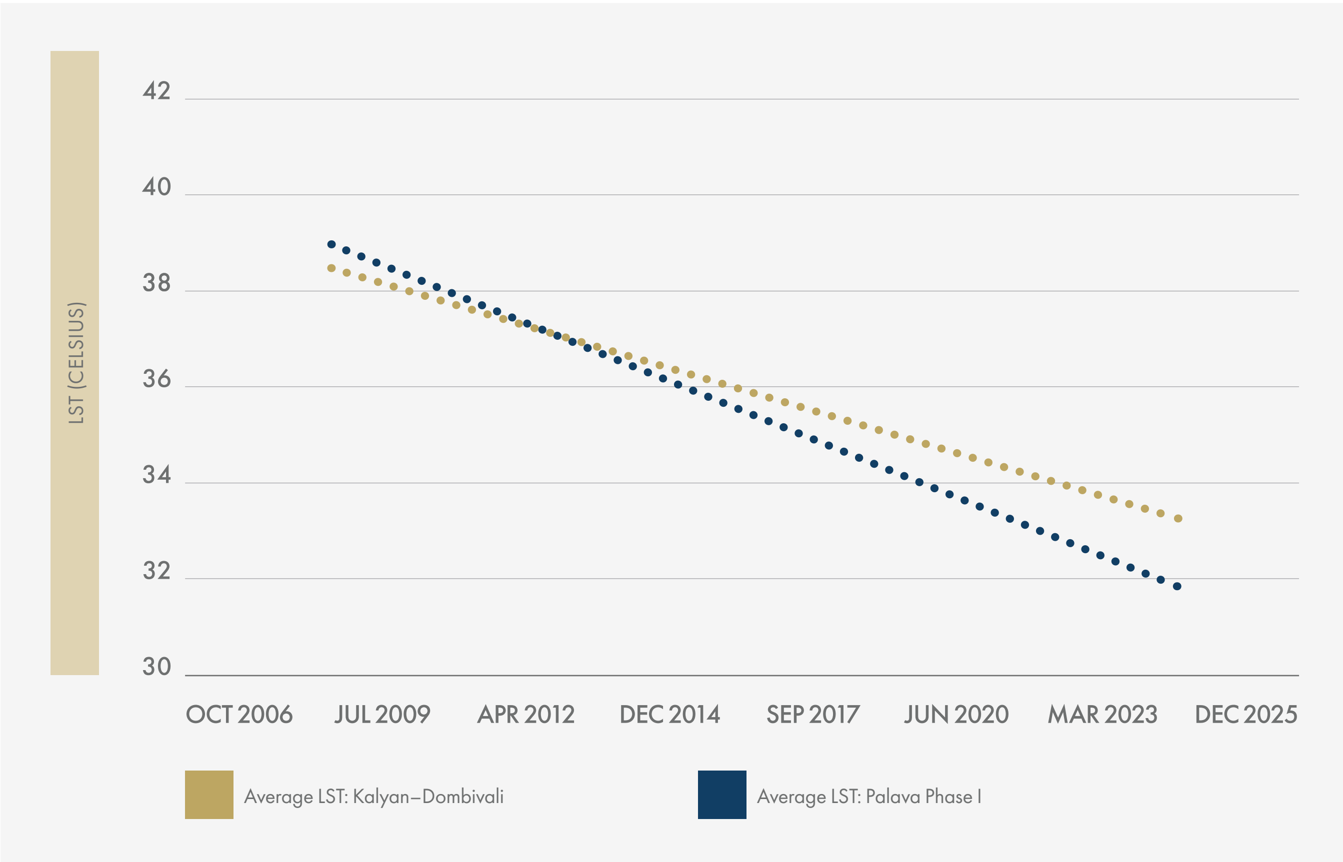
EXHIBIT 3.12 **TIMELINE OF AVAILABLE LST SNAPSHOTS (DARK BLUE) COMPARED WITH ON-GROUND MONITORING STATION DATA (LIGHT BLUE AND YELLOW)**



Palava City has three monitoring stations as of now. For increased granularity and spatial information, addition of multiple stations starting with the highlighted 'spots' in Table 1, is recommended. This will not only provide a more accurate understanding of evolving heat patterns but also allow for in-depth monitoring and evaluation of implemented cooling solutions.

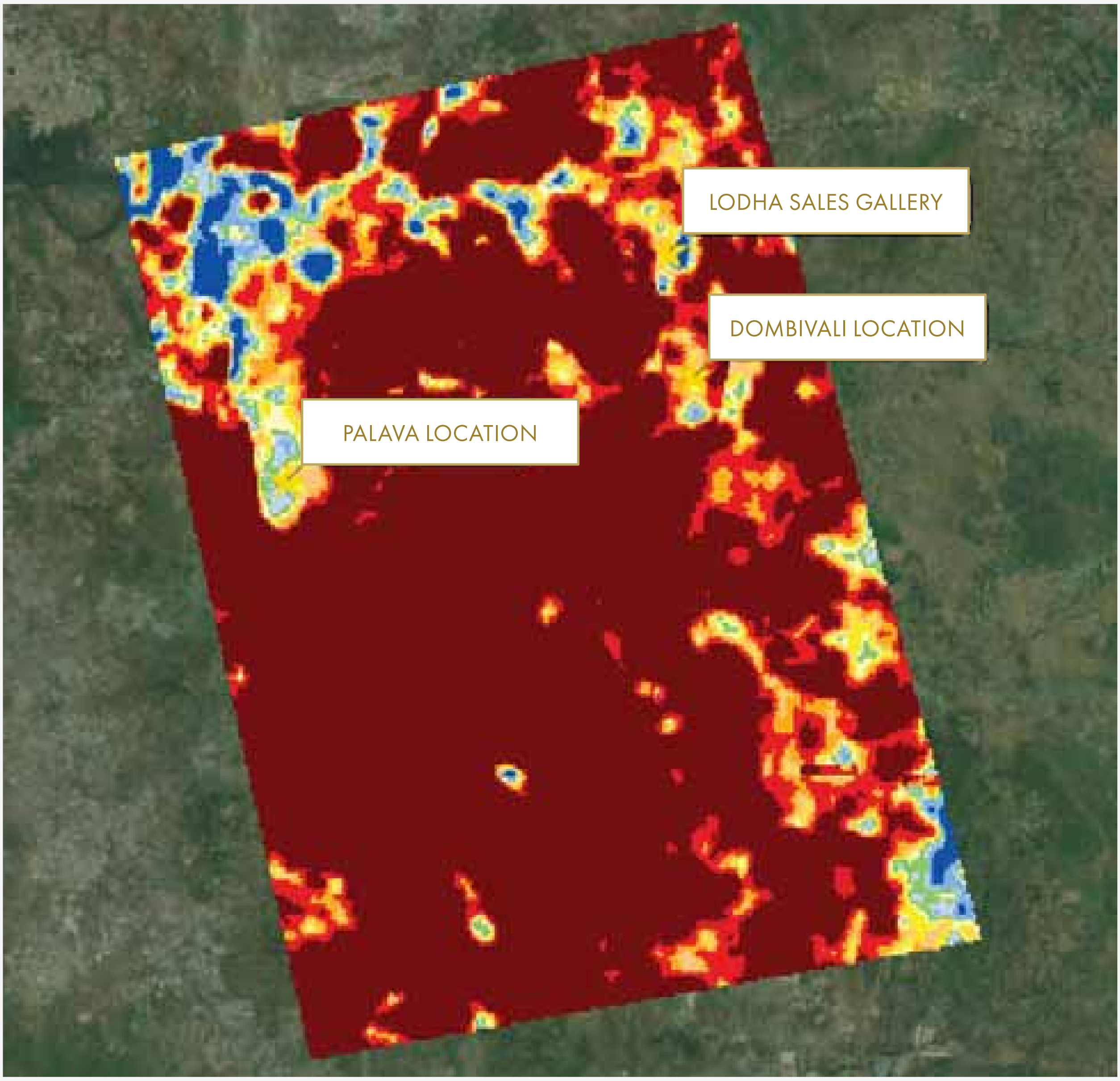
Exhibit 3.13 below outlines how heat stress has evolved in Palava Phase I since 2008. The linear average trendline for temperature (measured in LST averaged across the entire bounded area) drops by almost 7°C over the observed time period. In comparison, the temperature in the neighbouring Kalyan–Dombivali reduces over the same period, although at a markedly lower rate than in Palava Phase I.

EXHIBIT 3.13 **AVERAGE LST IN KALYAN–DOMBIVALI AND PALAVA PHASE I**



This trend could be an indication of the overall cooling of the local micro-climate, with Palava Phase I cooling even more rapidly than its surroundings.

EXHIBIT 3.14 **LST SNAPSHOT OF THE LOCAL AREA IN APRIL 2023**



Palava City locations are clearly cooler than their surroundings except for the river basin in the north and west of Palava City Phase I. This local cooling can be seen in the LST map above, depicting the temperature difference between Palava and neighbouring areas (refer to Exhibit 3.14).

KEY TAKEAWAYS

According to LST estimates, Palava Phase I has cooled by almost 7°C between 2008 and 2023. Certain areas with low greening rates are significantly warm.

Now, Palava's Phase I's maximum temperature is 3°C lower than that of Kalyan–Dombivali and 2°C lower than that of Mumbai as observed in 2023.

Heat islands in Casa Gold, just north of SH 76, and a thin line (railway belt) along the eastern border of Palava Phase I have grown over the past decade.

Palava Phase I was a marked 1.2°C warmer than Kalyan–Dombivali on average in 2008, following which the difference has increased significantly, and Palava Phase I has cooled much more rapidly than its neighbouring areas.

The active highway (SH 76) cutting through the northern sector (Casa Gold) causes a pronounced increase in heat stress during the hottest period of the year (April).

The western border of Palava Phase I has been steadily cooling over the same period, due in large part to increased greenery along that belt. The hottest period according to satellite data and on-ground monitoring differed by nearly three weeks, validating that an increased combination of the two is required.

LIMITATIONS

1. Current method of the assessment only allowed to capture the effect of UHIs and their correlation with land use in a limited manner. An comprehensive study using the Normalised Difference Vegetation Index (NDVI) will be taken up in the future to establish those co-relations.
2. There are only 3 on-ground monitoring stations that may have resulted in some in-accuracies. Increased on-ground monitoring will allow to accurately assess heat stress distribution and monitor the effectiveness of any sustainable cooling interventions that is be implemented.
3. Satellite-based mapping requires increased digitalisation of maps and masterplans due to which a detailed imaging could not be captured at the block level.

NEXT ACTIONS

The preceding analysis has helped lay the groundwork for follow-up action both at the analytical and interventional levels. The next actions have been devised following the initially developed framework of ICE — Ideate, Create and Enable.

EXHIBIT 3.14 **IDENTIFIED NEXT STEPS**

1 IDENTIFY HOT SPOTS	2 CREATION OF DATA REPOSITORY	3 ENABLE ON-GROUND ACTIONS	4 ENABLE IMPROVED INFRASTRUCTURE PLANNING	5 ENABLE PUBLIC POLICY DISCOURSE
Heat maps can help identify areas within a city that are significantly warmer than others. These hot spots often coincide with regions that have extensive concrete or asphalt surfaces and minimal vegetation.	Baseline mapping through Heat maps and installation of local weather stations is being planned to create a data repository to capture the pre and post intervention Information and results	1. Increasing green spaces 2. Improving building designs in hot spots to mitigate the urban heat island effect. 3. Integration of smart surfaces	1. Predict energy spikes from cooling to help utilities plan for peak demand and minimise power outages. 2. Inform on building design and materials selection	1. Draft strategies and interventions for action of local authorities during heat waves. 2. Guidelines and capacity building for reducing urban heat island from the built environment.
IDEATE	CREATE	ENABLE LOCAL & NATIONAL ACTIONS		
COMPLETE	NEXT ACTIONS			

Next steps in the process

The Accelerator in its first year has already mapped the hot spots. The next action is to initiate creation of data repository and take subsequent actions. These steps will help communities, industries and policymakers better understand and mitigate the risks associated with extreme heat, ultimately creating more resilient and sustainable urban environments.

CREATION OF DATA REPOSITORY

1. Conduct more in-depth studies using the NDVI to capture the effect of UHIs and their correlation with land use.
2. Increase on-ground monitoring to more accurately assess heat stress distribution and monitor the effectiveness of sustainable cooling interventions.
3. Ensure increased digitalisation of maps and masterplans for more accurate satellite-based mapping.
4. Create awareness and build capacity for the uptake of heat mapping activities as part of the master planning process within cities.

Data framework required to be captured for creating a data repository of the heat map pattern over the years is attached in Appendix 1.

Enable local actions

Implement heat resilience strategies at the community level such as those summarised in the following table:

TABLE 3.1 **INTERVENTION TABLE ADAPTED FROM BEATING THE HEAT AND EXTREME HEAT BY UNEP AND RMI AND RESILIENCE METRIC BY DR IDA SAMI**

INTERVENTION	DESCRIPTION	IMPACT
Green Infrastructure	Incorporation of vegetation, green/cool roofs, green walls and permeable pavements	Reduces UHIE, lowers surface and air temperature, improves air quality
Blue Infrastructure	Incorporation of water bodies, fountains and misting stations	Provides cooling effects, enhances thermal comfort
Smart Surfaces	Use of materials that reflect more sunlight and absorb less heat	Reduces heat absorption, lowers surface temperature
Reconditioning Unutilised Spaces	Provision of community cooling centres	Provides respite from heat
Heat Wave Predictive System	Development of a heat alarm system to predict and notify the unusual temperature expected at the local level	Allows Discoms to prepare for upcoming surge and prevent power outages

Enable improved planning

The integration and construction of heat-resilient infrastructure such as sustainable and thermally comfortable buildings and houses with passive design strategies included at the time of construction should be encouraged. In addition, smart surfaces such as cool/green roofs and walls, light-coloured pavements and roads and other nature-based solutions should be integrated to reduce the overall micro-climatic temperature within the city. With the integration of passive design strategies and smart surfaces, city authorities, along with Discoms, could create a framework and test strategies for predicting heat waves and peak demand due to cooling. This will help manage peak demand and smoothen the energy demand curve.

Enable public policy discourse

Support for policy changes that protect end-users from extreme heat.

1. Draft strategies and interventions to mitigate heat stress during heat waves.
2. Develop guidelines for building capacity of local authorities and at the national level to reduce the UHIE from the built environment.
3. Create awareness and build local capacity for the uptake of heat resilience solutions in communities.

WAY FORWARD

In conclusion, the escalating threat of extreme heat due to climate change necessitates a comprehensive and proactive approach. The way forward involves a two-pronged strategy: rigorous research and strategic implementation. Research should focus on understanding the correlation between UHIs and land use, enhancing on-ground monitoring and leveraging digital technologies for accurate mapping. In terms of implementation, the focus should be on adopting heat resilience strategies at the community level, leveraging policy incentives for climate resilience investments and advocating for worker protection in extreme heat conditions. By integrating these steps, we can navigate and test the identified challenges of extreme heat, safeguard our economies and ensure the well-being of communities. The time to act is now, as heat resilience is not a luxury but a lifesaver.

APPENDIX – 1: DATA REQUIRED FOR BUILDING REFERENCES

TABLE 3.2 **DATA REQUIRED FOR BUILDING DATA REPOSITORY**

DATA	METHODOLOGY	USE CASE FOR PALAVA
Temperature and relative humidity data (increased data from sensors in line with Excel file supplied by Lodha team)	Increased sensor data with location information paired with interpolation procedure for spatial analysis	• Heat index mapping • Advertising claims and showing improvements over time • Spatially understanding thermal comfort may allow strategic decision making in terms of urban cooling interventions and investments
Dry bulb Temperature	Increased sensor data with location information paired with interpolation procedure for spatial analysis	• Dry bulb temperature is important for determining material proprieties, insulation requirements, and the design of structures necessary to withstand temperature extremes • Dry bulb temperature plays a vital role in energy consumption and HVAC systems. It helps determine cooling or heating needs, set temperature control parameters, and optimise energy efficiency • Can help identify AC and other urban cooling infrastructure needs
Wet bulb Temperature	Installation of digital psychrometers to measure WBT or manual measurements through continuous on-ground monitoring of temperature, humidity, wind speeds	• Wet bulb temperature analysis will allow for assessment of human and thermal comfort outside – a more accurate assessment of the need for cooling interventions than land surface temperature • Spatially understanding thermal comfort may allow strategic decision making in terms of urban cooling interventions and investments
Boundary files in GIS-ready formats for Palava phased areas	Tracing areas or conversion of CAD files into shapefile formats	• More precise estimations of the earlier analysis • Clear boundaries for analysing different phases/areas within Palava City
Very High-Resolution (VHR) satellite data for purchase	Replicated approach using Very High-Resolution (VHR) satellite data	• More granular understanding of hot spots within Palava areas • Daytime vs. night-time analysis • Informing identification of ideal placement opportunities for NBS
UHIE	Combination of remote sensing, manual measurements, climate modelling, and more.	• The UHIE can show how the urban build-up of Palava impacts temperatures in the city differently from surrounding more rural areas – this can be assessed through a combination of satellite and on-ground monitoring approaches • The CARBSE methodology on measuring UHIE is in the process of being developed. It is a worthwhile but time-consuming exercise that is appropriate when deep, granular analysis is required for planning exercises. The decision-tree for deciding what kind of analysis is needed for different contextual requirements can be found in Figure 11 below.
Land Use/Land Cover	Classifications based on remote sensing, aerial photography, and field surveys	• Better understanding of changes in the built environment can be assessed in correlation with associated climatic observations (temperature, heat index, thermal comfort)

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CHAPTER 4

Embodied Carbon Reduction:
Pathways and Prospects for Sustainability

CONTEXT

Evolution of Construction in India

For centuries, traditional construction methods used locally available materials, predominantly mud and mortar, to build simple yet sustainable structures. The earliest homes from the Indus Valley civilisation, built of stone, mud bricks, and timber, were essentially three-storey structures featuring courtyards in the centre and a standard drainage system connecting them. These structures harmonised with the environment and offered natural light and thermal comfort. This vernacular architecture required skilled workmanship and was labour-intensive and time-consuming to construct.

Over time, building techniques evolved to meet the changing requirements of societies. Today, the booming population and pressure from rapid urbanisation have transformed India's buildings sector, marked by a transition from traditional mud and mortar to contemporary methods focused on speed and scale. Modern construction practices with advanced formwork techniques brought about a paradigm shift towards fast and more standardised construction processes, enabling developers to meet the growing housing demand in a cost-effective and resource-efficient way.

India's buildings sector transformation is a story about new construction, resulting in nearly 500 million metric tons of carbon dioxide (CO_2e) emissions in **embodied carbon (EC)** annually. India is set to more than double its building square footage over the next two decades; these embodied emissions, if unabated, could nearly double. It is critical to align speed and scale with environmental stewardship and pave the way for building a climate-resilient housing sector for future generations.

Significance of Embodied Carbon in the Buildings Sector

Today, 35% of India's population lives in urban areas, a proportion expected to increase to 43% by 2035. India's urban population is projected to grow from about 483 million in 2020 to 607 million in 2030 and 820 million by 2050.

Furthermore, over the next 20 years, India's total building space is projected to more than double. By 2030, over 70 cities in India will have a million-plus inhabitants, meaning the largest share of the new building stock will be urban residential construction. This implies that the vast majority of the building stock that will exist in 2050 is yet to be built; consequently, EC emissions will continue to increase drastically if not addressed urgently. As embodied emissions occur at the beginning of the building life cycle, they will account for almost half of the new construction emissions during the crucial window of India's urbanisation, its energy transformation, and its role in the global fight against climate change.

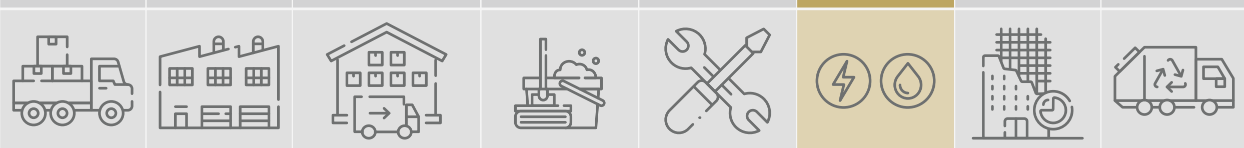
In this convergent moment of development and urbanisation, India can 'build right the first time' — avoiding the carbon lock-in effects associated with carbon-intensive building materials and inefficient construction. Indeed, this decisive decade is a critical window of opportunity to develop a resilient built environment that minimises the energy and carbon intensity of the real estate and infrastructure sectors.

In the buildings sector, EC refers to the green house gas (GHG) emissions associated with the manufacturing, transportation, installation, maintenance, and disposal of building materials. These emissions can be significant; they currently account for approximately 11% of global emissions and nearly 40% of India's buildings sector CO_2 emissions. EC does not include the carbon emissions associated with building operations (e.g., from on-site fossil fuel combustion or electricity use). EC is calculated as global warming potential (GWP) and expressed in carbon dioxide equivalent units (CO_2e).

EC is measured using the life-cycle assessment (LCA) methodology to calculate the environmental impact of a product or building over various life-cycle stages, from extraction of raw materials, manufacturing processes involved, and transportation of materials to the construction site to end-of-life disposal or recycling. The life-cycle phases are explained in Exhibit 4.1. In building construction, LCAs are performed at the building level, referred to as whole-building LCA (WBLCA), and at the product or material level. At the product level, the LCA results (often focusing on the A1–A3 life-cycle phases) are reported in environmental product declarations (EPDs), which can help consumers understand the ecological impact of the selected material.

EXHIBIT 4.1 **BUILDING MATERIAL LIFE-CYCLE ASSESSMENT PHASES**

PRODUCT PHASE		CONSTRUCTION PHASE	USE AND MAINTENANCE PHASE			PRODUCT PHASE	
Raw material supply and transport	Manufacture products	Transport to site and installation	Use and maintenance	Repair and replacement	Energy and water use	Deconstruction and demolition	Waste transport, processing and disposal
A1–A2	A3	A4–A5	B1–B2	B3–B5	B6–B7	C1	C2–C4



Embodied Carbon   Operational Carbon

Source: Transforming Existing Buildings from Climate Liabilities to Climate Assets Report, RMI

Most EC in buildings comes from emissions during product manufacturing, including raw material supply and extraction, transport to processing and manufacturing facilities, and manufacturing activities. In the LCA methodology, this is known as the product phase (sometimes referred to as cradle-to-gate), encompassing life-cycle phases A1–A3. These emissions play an important role in averting the worst effects of climate change. Unlike emissions from building operations, which are constant and can be reduced over time, they occur all at once and are committed to the atmosphere before a building is occupied, creating a significant spike of emissions that cannot be remediated. If unchecked, these embodied emissions could account for more than half of India's overall carbon footprint of new construction between now and 2050.

EC is an emerging area of interest in the building design and construction industry in India and globally. Lodha and other forward-thinking industry leaders across the globe are including EC reduction strategies in standard practice in pursuit of its many benefits. These actions include a growing momentum towards procuring low-carbon cement, concrete, and steel. These materials dominate building construction and are considered high-impact, low-cost opportunities to reduce the overall EC footprint of buildings. Manufacturers have met this demand with market-ready solutions born of decades of research and real-world trials, as well as emergent materials and technologies that promise increased EC reduction with net-zero-emissions manufacturing. Annexure A presents an overview of the impact of EC on cement, concrete, and steel.

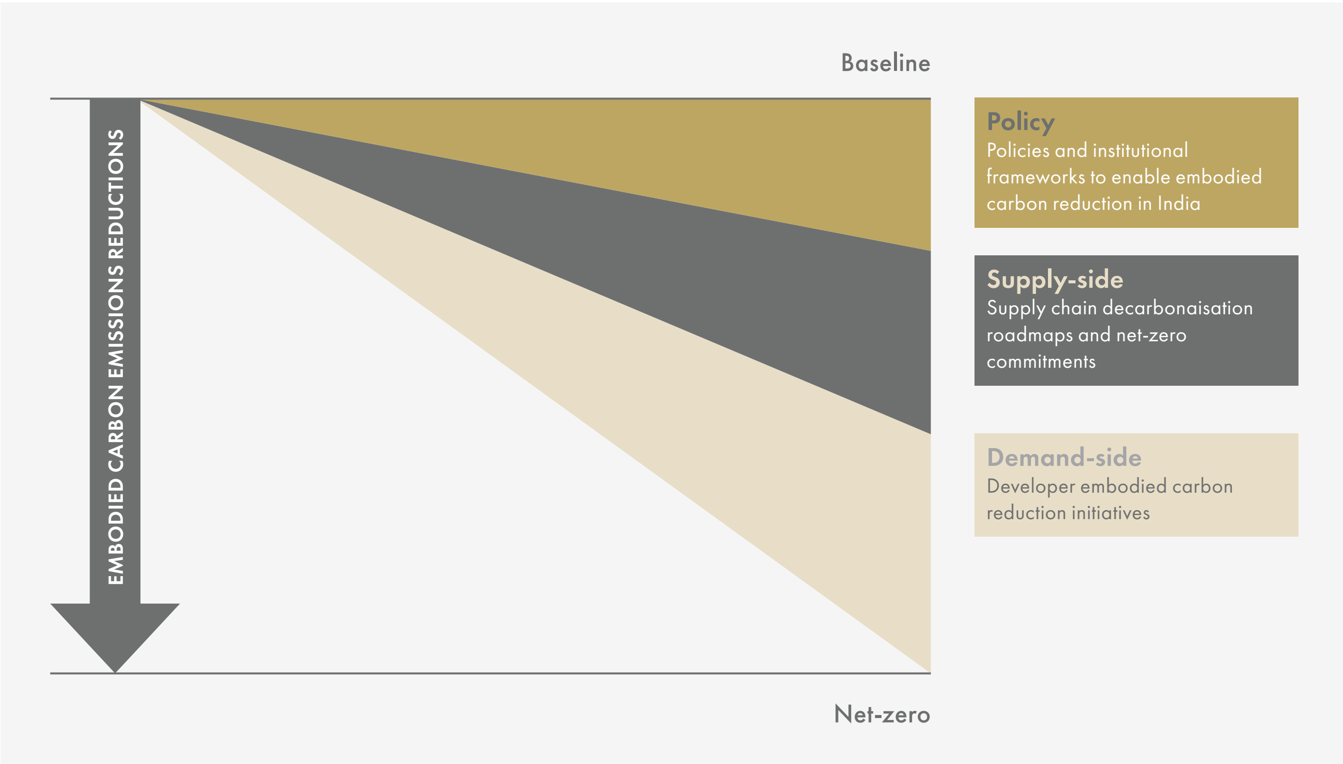
This section presents the results of an EC benchmarking study conducted for Lodha's typical high-rise reinforced concrete multifamily residential building, a building typology that represents the bulk of upcoming construction in India, driven by the imperative to accommodate the increasing urban population. This benchmarking study is used to chart a path to net-zero EC using reduction strategies with short-, medium-, and long-term potential. The baselining exercise revealed that cement, concrete, and steel materials contribute over 50% of the EC emissions, establishing them as a critical focus area for carbon reduction. In the future, a similar benchmarking analysis, incorporating third-party verification, will be conducted for other common typologies (such as composite, precast, and industrial warehouses) to identify materials that lower EC the most.

This report provides an overview of Lodha's current EC reduction strategies to drive the demand for low-carbon cement, concrete, and steel. It also includes a summary of insights from consultations with supply chain leaders, outlining the opportunities and challenges in decarbonising these sectors. This benchmarking study shows that aluminium will also be an essential opportunity area for EC reductions in Lodha's buildings, however, it was not analysed in this study. Subsequent strategies will be developed to reduce the EC footprint of Aluminium, Glass, and other building materials.

STRATEGIES TO REDUCE EMBODIED CARBON IN THE BUILDINGS SECTOR

Reducing EC in materials is an emerging focus area in India and globally, and the momentum is growing. The burgeoning policy and programme landscape can help catalyse action towards an energy transition in the buildings sector. Industry associations are developing technology roadmaps to transition to low-carbon manufacturing, while progressive developers in construction are pledging to cut EC emissions and promote decarbonisation. These initiatives are summarised in Annexure A. Together, these efforts could drive down EC emissions in the built environment and shape the trend towards low-carbon building materials, as shown in Exhibit 4.2.

EXHIBIT 4.2 **COLLECTIVE ACTION TO REDUCE EMBODIED CARBON EMISSIONS**



Source: RMI

Reduction in EC in materials has begun to take shape in India and globally. Design teams must be aware of EC priorities from the outset of a project and integrate EC targets into the design process, especially during the early project planning and design phases when some of the most impactful decisions are made.

Studies show that careful specification of materials alone may result in total EC reductions of 30%–50% at cost premiums of less than 1% using commercially available low-EC concrete, steel, and other building materials. Inspiring low-EC construction projects around the world source local materials, optimise structural systems, reduce concrete and steel usage, and use bio-based carbon-storing materials. These are just a few examples of effective EC reduction strategies that can be deployed at various stages of project execution, as summarised in Exhibit 4.3.

EXHIBIT 4.3 **BUILDING-SECTOR STRATEGIES TO REDUCE EMBODIED CARBON**

Source: From the Ground Up Report, NIUA and RMI

Climate targets in India cannot be met unless the building design and construction industry meaningfully reduces EC emissions. The economics of low EC will also encourage increased recycling, supporting India's resource-efficiency policy efforts related to construction-and-demolition waste management, procurement of materials containing recycled content, and scrap metal recycling. Such opportunities to reduce EC come with the following benefits to society:

1

Mitigating climate change

Most EC emissions occur before a building is occupied and cannot be mitigated. Reducing EC helps address large amounts of GHG emissions in less time, lowering overall carbon emissions and limiting the impact of climate change.

2

Transitioning to a low-carbon economy

Transitioning to a low-carbon economy is critical to achieving India's nationally determined contributions (NDC) target of net-zero emissions by 2070 and international climate goals such as the Paris Agreement's target to limit global warming to well below 2°C. Reducing EC in buildings can support the transition to a low-carbon economy by driving the decarbonisation of various sectors and lowering the air pollution associated with material manufacturing and construction. It will also encourage local circular economies through material recycling, waste reduction, and building reuse, thus improving public health.

3

Minimising resource depletion

Lowering EC often involves using more resource-efficient materials and processes. This can reduce the demand for finite resources, such as raw materials and fossil fuels, and help preserve natural resources for future generations. Additionally, the efficient creation of low-EC materials often lowers air and water pollution.

4

Enhancing construction energy efficiency

Many low-carbon construction processes and materials are also energy efficient, which reduces energy consumption in manufacturing and construction. This, in turn, can result in cost savings and low material costs for buildings and infrastructure.

5

Green building certifications and environmental, social, and governance reporting

Many countries and organisations are implementing green building certifications and regulations that encourage or mandate low EC in construction projects. Complying with these requirements can enhance a project's marketability, attract environmentally-conscious investors, and ensure compliance with emerging sustainability standards.

6

Encourage green economic development

The growing market for low-EC materials can create a competitive market and new jobs. As these high-performance materials are developed, they can add to India's economy and leadership in the climate industry.

ANALYSIS OF LODHA'S TYPICAL HIGH-RISE REINFORCED CONCRETE MULTIFAMILY BUILDING

Lodha has set an ambitious target to reduce the EC footprint of its overall portfolio by 5% and of specifically concrete by 10% year-over-year through progressive revision of the design mix — contingent on the accomplishments and strategies of its supply chain partners. This target is being pursued through the following systematic approach:

1. **Establish** a baseline (in kilograms CO_2e per square metre [kg CO_2e/m^2]) for the EC footprint of a typical residential building in the Indian context (function of material quantities and their corresponding GWP impact).

2. **Evaluate** the data through a peer-reviewed process and address any uncertainties related to EC footprint calculation.

3. **Engage** with sustainability leads of significant suppliers and identify low-carbon alternatives and EC reduction strategies.

4. **Experiment** with low-carbon alternatives, conduct performance analysis, and document the results.

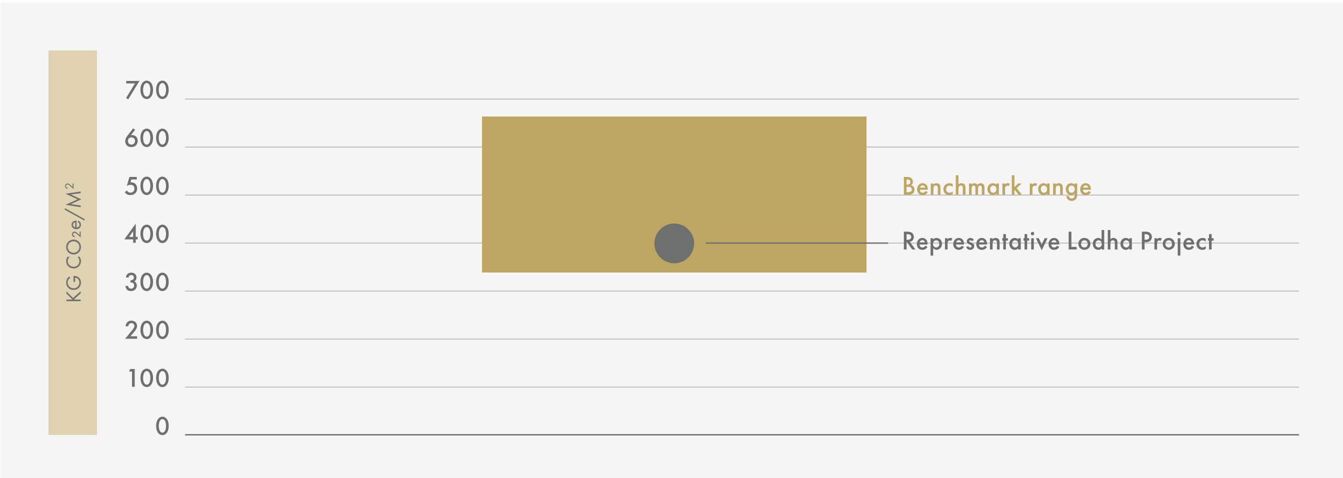
5. **Encourage** circular economy by creating an ecosystem that tracks and reduces waste and identifies reuse streams.

6. **Envision** a roadmap for EC reduction through material-specific emissions targets and trajectories.

The Accelerator team conducted a comprehensive baselining study of the EC footprint of various materials used in a typical high-rise reinforced concrete multifamily residential building. The analysis modelled a representative structure of this building type to generate an estimate of EC per square metre. The analysis included emissions resulting from material extraction, manufacturing, and construction (life-cycle stages A1–A5) and excluded emissions during building occupation and end of life. The study provided valuable data to compare the typical Lodha project against global benchmarks, test current assumptions about EC reduction strategies, and identify high-impact opportunities to reduce the EC footprint.

The analysis indicates that the EC footprint of a typical reinforced concrete multifamily residential building by Lodha is 387 kg CO_2e/m_2, as shown in the exhibit below. This is notably modest compared with the range determined by an RMI benchmark analysis, which includes data from the Carbon Leadership Forum's 2017 Embodied Carbon Benchmarking Study and various other case studies. The Accelerator team also analysed the breakdown of EC emissions from the individual materials.

EXHIBIT 4.4 **EC FOOTPRINT OF A TYPICAL REINFORCED CONCRETE MULTIFAMILY RESIDENTIAL BUILDING BY LODHA COMPARED WITH BENCHMARK RANGES FROM THE CARBON LEADERSHIP FORUM AND RMI**



Source: RMI Analysis

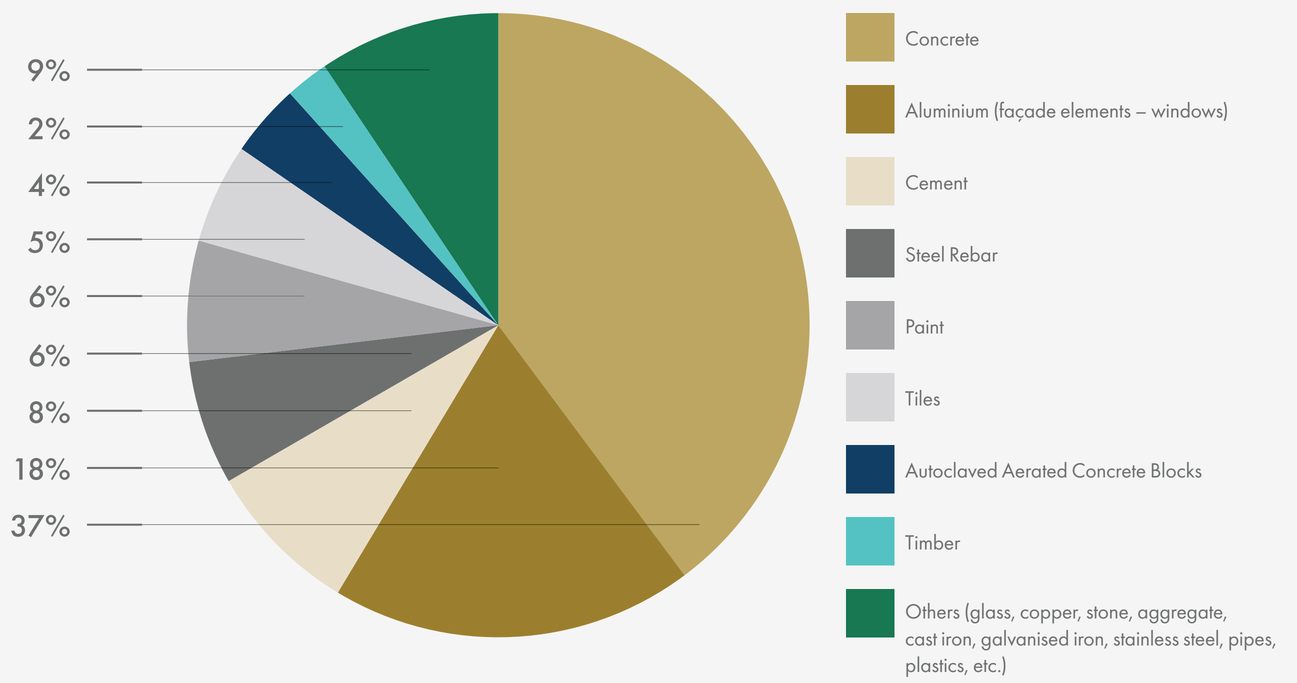
Limitations of the study

For this analysis, accurate data at the extraction, procurement, manufacturing, construction use, and end-of-life disposal stages was hard to ascertain. In the absence of transparent emissions disclosures, the analysis team gathered data through supplier consultations and from international databases such as the the Inventory of Carbon & Energy's GaBi, International Finance Corporation's EDGE, and the Embodied Carbon in Construction Calculator. Reliance on these databases poses the risk of regional biases and generalisation of emissions factors.

Typical Multifamily Reinforced Concrete Building WBLCA Results

The baselining exercise revealed that cement, concrete, aluminium and steel rebar contribute up to 70% of the EC emissions of the typical reinforced concrete multifamily building modelled in this study (see Exhibit 5 on the previous page), establishing them as key focus areas for carbon reduction.

EXHIBIT 4.5 **CEMENT, CONCRETE, ALUMINIUM AND STEEL REBAR CONTRIBUTE UP TO 70% OF THE EC EMISSIONS OF A TYPICAL REINFORCED CONCRETE MULTIFAMILY BUILDING MODELLED IN THIS STUDY**



Note: The cement category refers to cement that was mixed on-site rather than brought to the site as ready-mix or precast concrete.

Source: RMI Analysis

Concrete emissions can be gradually reduced by 50%–65% using supplementary cementitious materials (SCMs) such as fly ash or ground granulated blast furnace slag (GGBS) and alternative cement materials (ACMs) such as limestone calcinated clay cement (LC3). The impact of these reductions on the overall EC footprint of a typical building can be up to 30%, thereby reducing the EC footprint of the building to approximately 260 kg CO_2e/m^2, with little to no cost premium. Lodha is systematically and gradually increasing the use of SCMs and ACMs and consistently conducting performance analysis to build confidence in and scale the use of tested cement mixes.

Most buildings in India today are made of reinforced concrete and steel frames, and India is the second-largest producer of these materials in the world. In the next 30 years, India's steel demand is estimated to more than quadruple, while cement production is expected to increase as much as six times. The demand to build a growing, urban India is an opportunity to invest in leading technologies that give its cement and steel sectors a competitive edge. The Accelerator will help move these industries towards net-zero by piloting low-carbon initiatives in cement, concrete and steel. Subsequently, the Accelerator will develop strategies to reduce the EC footprint of other building materials and improve design practices with the aim to achieve low EC construction at or near cost parity with traditional products and approaches.

CHALLENGES AND OPPORTUNITIES IN TRANSITIONING TO LOW-CARBON CEMENT, CONCRETE AND STEEL

It is challenging to reduce EC in cement, concrete, and steel in India. From a manufacturer's perspective, transitioning to low-carbon materials and methods may require significant investment and specialised skills. From a consumer's perspective, using low-carbon materials often comes with additional costs, posing a challenge to widespread adoption.

To better understand the challenges and opportunities related to the production and adoption of low-carbon products in the construction industry, the Accelerator team conducted stakeholder consultations with several cement, concrete and steel manufacturers. Key insights and takeaways from these consultations are summarised below.

CEMENT AND CONCRETE

1

Cautious Approach

Architects, engineers, and building contractors tend to be cautious when adopting new products and processes, which is appropriate when safety is a primary concern. Stakeholders typically accept a low-carbon mix containing up to 40% GGBS and 25% fly ash, but they tend to exercise restraint when surpassing this composition. Misconceptions about the strength and performance of concrete using a greater ratio of SCMs have can affect sales.

2

Meeting Performance Requirements

To achieve the desired construction schedule, mixes with high SCM percentages must be designed to meet the de-shuttering criteria and appropriate slab cycle timelines. Mixes must also align with the workability aspects, including flowability and ability to pump, required for high-rise construction.

3

SCM Availability and Cost

Availability and cost of good-quality fly ash and GGBS vary by location. GGBS is scarce in North India, and across India long-term supply is expected to decline as blast furnaces and coal-fired power plants phase out. Procuring good-quality GGBS and fly ash to meet project needs is a challenge, with the former priced at ₹3,500–4,000 per metric tonne.

4

Policy and Monetary Incentives

Lack of sufficient policies, mandates, and monetary incentives for the production and uptake of embodied carbon products has delayed their production and adoption.

5

Low Awareness

Low awareness and availability of EPDs, low-EC materials, and sustainable construction practices contribute to the limited uptake of low-carbon products.

STEEL

1

Scrap Usage

Recycled steel manufacturing uses 70%–80% scrap, with domestic sourcing from various locations supplemented by imported scrap from the Middle East.

2

Misconceptions

The Government of India's Ministry of Steel does not recognise the classification of steel producers as primary or secondary. Any steel that meets the Bureau of Indian Standards is considered acceptable for government projects. However, misconceptions in the market regarding the strength and performance of recycled steel products must be addressed.

3

Energy Costs

Electricity generated using renewable energy can be costlier than that from the grid in some regions in India due to additional wheeling and transmission charges. This added cost offsets the advantage of low energy charges for solar power used in steel manufacturing.

4

Reliable Electricity Supply

Reliable electricity supply is of utmost importance in steelmaking, as any interruption or inconsistency in power can lead to severe production disruptions and economic losses. Solar energy alone cannot meet the high power demands due to limited space in steel plants for on-site solar installations.

To sum up the discussions with supply chain partners, barriers to the production and adoption of low-carbon products include emissions-related data scarcity, perceived uncertainty around field performance, limited policy-push and demand-side market signals, low awareness of market-ready low-EC products, supply chain challenges, and evolving regulatory and green building certification targets concerning EC.

Overcoming these obstacles will be vital in promoting the widespread use of low-carbon materials in the buildings sector. Collective action across the value chain is essential to raise awareness, clear misconceptions, and stimulate demand for and market acceptance of low-carbon products. Increased focus on research and development, education, and workforce development will be critical in catalysing these opportunities. Work to advance these industries in India and globally is underway, driven by the growing momentum of demand-side commitments by international governments, Lodha and other developers, and other large end-users. International coalitions are bringing demand- and supply-side stakeholders together to share knowledge and co-create reduction targets, while industry groups are developing roadmaps to identify the technologies and strategies necessary for decarbonisation. The Government of India has spearheaded numerous national and state programmes to support decarbonisation in the cement, concrete, and steel industries. These efforts are summarised in Annexure A.

Lodha's ambitious target to reduce the EC footprint of its overall portfolio by 5% and of concrete specifically by 10% year-on-year is contingent on the success of these industries. Through the Accelerator, Lodha is committed to working with industry partners to reach these goals. The Accelerator aims to facilitate the generation of evidence, foster cross-border partnerships, and signal tangible demand to accelerate the production and adoption of low-carbon building materials in India.

ACTION PATHWAYS

Strategies for Concrete and Steel

The journey begins with a careful assessment of current design, procurement, and construction practices. As a major player in India's real estate development landscape, Lodha is reducing the EC footprint of buildings through effective design decisions and plans to drive demand for low-carbon building materials by conducting pilots and providing a business case for manufacturers to produce these low-carbon building materials.

Accurately engineered solutions inherently foster sustainability. The first step is developing optimal and modular designs with an integrated approach where all design trades (architecture, structure, façade, and building services) work together to right size the quantity of material required for construction.

The next step is to identify the materials used and quantify the baseline EC for each to provide meaningful long-term material-specific EC reduction targets. Additionally, immediate actions are identified to enable gradual progress towards these long-term goals.

Lodha is actively pursuing a whole-systems approach to reduce EC in its building developments while working towards an annual EC emissions reduction goal of 5% to ultimately achieve net zero — contingent on the accomplishments and strategies of its supply chain partners. To achieve these goals, Lodha has outlined strategies spanning design, procurement, and construction, summarised in Exhibit 4.6.

EXHIBIT 4.6 **EMBODIED CARBON REDUCTION STRATEGIES BEING DEPLOYED BY LODHA**

	DESIGN	PROCUREMENT	CONSTRUCTION
Measure	• Maintain appropriate plan aspect ratios. • Choose the optimum column grids for the given occupancy. • Integrate modular concepts into the design, where relevant. • Retain vertical and horizontal symmetry where possible. • Position lateral elements in buildings strategically to efficiently counteract lateral forces. • Maintain efficient vertical load paths from upper levels down to foundations. • Implement post-tensioning in long-span members to counteract the effects of self-weight load.	• Incorporate explicit EC goals in general conditions of contract, bids, tendering documents, and procurement documents and set building-/material-specific targets, progressively tightening carbon limits over time. • Ensure contractors are aware of EC requirements. Regularly assess and continually monitor suppliers' emissions performance to ensure compliance.	• Monitor and report the EC associated with different construction activities to identify areas for improvement and track progress over time. • Create single-stream waste collection systems at construction sites to increase the waste recovery rate and identify areas to use construction waste and recycled products for other purposes.
Improve	• Increase the proportion of low-emissions concrete to 30% by 2025 and 50% by 2030, and eventually zero-carbon concrete (with carbon capture utilisation and storage [CCUS]) by 2050. • Set an EC budget for upcoming projects based on LCA calculations for similar buildings or case studies. Document the as-built EC content for the selected buildings and publish the data. • Incorporate green spaces, green roofs, and permeable surfaces to promote biodiversity and absorb carbon dioxide.	• Identify the right vendors for partnership through strategic product scoping and improve the resource efficiency of production processes. • Promote the practice of near-sourcing and encourage vendors to set up manufacturing facilities in Lodha's industrial parks (supports job creation and EC reduction). • Preferentially purchase from suppliers that incorporate high recycled content, electric arc furnaces/kilns, waste heat recovery, alternate fuels, and clean electricity supplies. In the long term, procure materials from plants using CCUS and hydrogen. • Explore alternative cementitious materials and products that supplement or replace a portion of cement with fly ash, slag, silica fume, or LC3, have low carbon emissions, and can reduce the overall carbon footprint. • Explore prefabricated components and materials that incorporate recycled aggregates, such as recycled concrete or industrial by-products, which can reduce demand for primary (virgin) materials and associated emissions.	• Improve construction efficiency to minimise waste material and promote the recycling of construction and demolition waste. • Target a 100% recycling rate for aluminium waste and reduce the waste of steel reinforcements and concrete to zero. • Explore the use of energy-efficient construction machinery and equipment, including those powered by clean energy sources, to reduce emissions during construction activities. • Maintain rigorous quality standards in construction to improve the durability of structures with minimum maintenance during the lifetime of buildings.

EXHIBIT 4.6 **EMBODIED CARBON REDUCTION STRATEGIES BEING DEPLOYED BY LODHA (CONTINUED)**

	DESIGN	PROCUREMENT	CONSTRUCTION
Engage	• Engage with subject matter experts and supply chain leaders to pilot pioneering solutions and incorporate best practices while providing training and awareness. • Develop confidence in low-carbon alternatives by measuring and reporting field performance. • Collaborate with innovators to gather empirical evidence regarding the application of novel, low-carbon products aimed at informing policymakers.	• Raise awareness among procurement staff and suppliers of the significance of EC and emissions reduction. • Explore possible partnerships for demand aggregation and provide the demand signals to the supply side to mainstream green products.	• Engage with vendors, contractors, and recyclers to create a circular economy. • Divert construction and demolition waste away from landfills through circularity and efficient waste management techniques. • Educate construction personnel about the importance of EC reduction and provide training on waste management and sustainable construction practices.

Source: RMI Analysis

Establishing a baseline of EC in building construction is an essential first step in measuring the success of EC reduction strategies. The Accelerator conducted a comprehensive baselining study that includes the major material categories used in a typical multifamily building. This study provides valuable data to compare the typical Lodha project against global benchmarks, test current assumptions about EC reduction strategies, and identify high-impact opportunities to reduce Lodha's EC footprint. By deploying the complete set of strategies listed in Exhibit 4.6, combined with advancements in the cement, concrete, and steel sectors, it will be possible to reach net-zero EC in multifamily building construction.

A similar benchmarking analysis, incorporating third-party verification, will be conducted for other common typologies (such as composite, precast, and industrial warehouses) to identify materials that lower EC the most. Lodha's strategies, combined with projected advancements in the industry, can be tested against the results of each analysis to understand unique pathways and time lines to zero EC for each building type.

Given the cost, risk, and durability of alternative low-EC infrastructure, stakeholders are understandably cautious about adopting new practices. Lodha is making an inspirational first move by addressing EC. Going forward, the Accelerator aims to catalyse the adoption of low-carbon building materials by critically assessing the buildability and cost implications through pilots while providing a business case for manufacturers and confidence to consumers to adopt such low-carbon building materials. Achieving these ambitious goals will be a decades-long process, with revisions and adjustments to be made along the way. Lodha is well positioned to bring together innovators and experts to pilot and scale low-EC alternatives.

Subsequently, strategies will be developed to reduce the EC footprint of Steel, Glass, Aluminium and other building materials as well.

ANNEXURE A: GLOBAL LANDSCAPE OF LOW-CARBON CEMENT, CONCRETE, AND STEEL IN THE BUILT ENVIRONMENT

Cement, concrete and steel are some of the biggest emitters of CO_2 globally. Reduction in EC in materials has just begun to take shape in India and globally. The industrial infrastructure required to build a growing, urban India is an opportunity to invest in globally leading practices and technologies that represent a competitive edge rather than stranded asset risks.

I. Embodied Carbon of Cement and Concrete

Concrete is the world's most consumed material, second only to water, and a primary material used in the built environment. Cement, a primary ingredient, is responsible for about 90% of the emissions in concrete and accounts for 8% of the global anthropogenic CO_2 emissions. Cement consumption is a key indicator of construction activity, infrastructure development, and economic development in a country or region.

The increase in cement consumption is influenced by various factors, including population growth, urbanisation, industrialisation, government infrastructure investments, and economic conditions. India is experiencing rapid urbanisation, with the number of urban agglomerations comprising more than 1 million people expected to double by 2035 and a surge in construction activities to meet this growth.

Calcination, the chemical reaction that occurs during cement manufacturing, accounts for roughly 70% of the emissions from cement production. This process involves heating limestone (calcium carbonate) to produce lime (calcium oxide) and releases CO_2 as a by-product. Because these emissions are the result of chemical reactions, they cannot be reduced or eliminated by increasing energy efficiency or switching fuels. As such, the EC content of cement can be reduced by replacing a portion of the cement with SCMs such as fly ash and slag or using alternatives to portland cement.

The remaining 30% of the cement production emissions come from burning fossil fuels to heat the kilns required to produce clinker and the extraction and transportation of raw materials such as limestone and clay.

II. Embodied Carbon of Steel

Steel is a widely used material in the built environment and is valued for its strength, durability, and versatility. It plays a crucial role in various construction applications, including buildings, bridges, infrastructure, and industrial structures, and accounts for 7% of the CO_2 emissions globally. In India, steel production accounts for 12% of the CO_2 emissions. The primary source of these emissions is steelmaking — the process of producing steel from iron ore and other materials. The following primary methods are used in steelmaking:

1. Blast Furnace–Basic Oxygen Furnace (BF-BOF): This is a traditional method involving iron ore extraction in a blast furnace, followed by converting iron into steel in a basic oxygen furnace. This process is energy-intensive and emits substantial amounts of CO_2 due to the combustion of carbon-based fuels and chemical reactions.

2. Electric Arc Furnace (EAF): This is a more modern and energy-efficient method of steelmaking. Scrap steel is melted in an EAF using the heat generated by an electric arc. EAF steelmaking has a lower carbon footprint than BF-BOF, as it consumes less energy and relies on recycled steel. Notably, not all steel products can be made through EAF operations, meaning the BF-BOF process will stay and must have its own pathway to decarbonisation.

Efforts to develop low-carbon and carbon-neutral steel production methods include employing hydrogen-based direct reduction processes and using renewable energy sources to power steelmaking operations. These innovations mitigate the environmental impact of steel in the built environment and contribute to a more sustainable construction industry.

III. Enabling Conditions

The international community recognises these sectors as important opportunity areas to curb GHG emissions and avoid the worst effects of climate change. Global cement and steel associations are creating technology roadmaps to help members decarbonise manufacturing. Additionally, forward-thinking leaders in the buildings industry are committing to reducing EC emissions and integrating reduction strategies into standard practices. Together, these efforts are driving down emissions and shaping the trend towards zero-carbon cement, concrete, and steel.

Work to advance decarbonisation in cement, concrete, and steel manufacturing is underway, driven by demand-side commitments by governments, developers, and other large end-users. Several international coalitions are leading cement and steel decarbonisation by bringing stakeholders together to share knowledge, advance technology, increase demand, and set ambitious targets for low-carbon cement, concrete, and steel products.

Governments are leveraging their vast purchasing power to drive demand for low-carbon cement, concrete, and steel through green public procurement (GPP) initiatives.

a. International coalitions

Examples of multinational stakeholder coalitions working to decarbonise the cement, concrete, and steel industries:

SECTOR	INITIATIVE	TARGET	DESCRIPTION
Cement, Steel	Clean Energy Ministerial's (CEM) Industrial Deep Decarbonisation Initiative (IDDI)	Signatories to decide	CEM is a multistakeholder forum to promote policies and programmes that accelerate the global clean energy transition. CEM's IDDI is a global coalition of public and private organisations working together to standardise carbon accounting, establish ambitious public- and private-sector procurement targets, and incentivise investment in low-carbon cement and steel.
Cement, Concrete, and Steel	First Movers Coalition (FMC)	10% by 2030	FMC is a coalition of private-sector companies leveraging their purchasing power to catalyse markets for innovative clean technologies in the cement, steel, and other hard-to-abate sectors.
Steel	SteelZero and ResponsibleSteel	50% by 2030, net-zero by 2050	ResponsibleSteel is a global standard and certification initiative for socially and environmentally responsible net-zero steel. SteelZero is a global public commitment programme for steel purchasers.
Concrete	Concrete Zero	30% by 2025, 50% by 2030, net-zero by 2050	A global commitment programme for concrete purchasers.
Cement, Concrete, and Steel	Mission Possible Partnership	Net zero by 2050	A multistakeholder partnership empowering ambitious decarbonisation initiatives and resources by mobilising the entire value chain.
Cement, Concrete, and Steel	Science-Based Targets Initiative (SBTi)	Determined by participant	A global initiative for companies to develop science-based targets that define a path to reduce emissions in line with the Paris Agreement goals.

b. Green public procurement

Examples of nations with GPP policies that include concrete, cement, and steel:

REGION	MATERIALS INCLUDED UNDER GPP POLICIES		
	Cement	Concrete	Steel
China		X	
European Union		X	X
Japan		X	X
Netherlands		X	X
South Korea			X
United States	X	X	X

In India, various departments in the states of Kerala, Andhra Pradesh, Rajasthan, Odisha, Gujarat, Haryana, and Maharashtra have launched initiatives to make public procurement easy (direct procurement model), support innovation (innovation zone model, Make in India), and favour supplementary cementitious materials (SMEs) and startups (concessions, benefits, suo moto model).

c. National and global industry roadmaps

Examples of industry roadmaps exploring technologies and strategies necessary for decarbonisation:

NATIONAL GOVERNMENT INITIATIVES	STATE GOVERNMENT/PSU INITIATIVES	GLOBAL INITIATIVES
India's nationally determined contributions	HAL's e-procurement portal	Clean Energy Ministerial (CEM)
Smart Cities Mission and Climate Smart Cities assessment framework	NTPC assessment guidelines	Industrial Deep Decarbonisation Initiative (IDDI)
Government eMarketplace (GeM)	Direct procurement model (to make the procurement process easier in Kerala)	First Movers Coalition (FMC)
National Green Hydrogen Mission	Innovation Zone Model, Make In India campaign (support innovation in RJ, OR, GJ, HR)	SteelZero
Perform, Achieve, Trade (PAT) Scheme and Energy Conservation Amendment Bill (MoP)	Concessions, Benefits, Suo Moto Model (favours SMEs and startups in KA, AP and MH)	ConcreteZero

d. Demand-side embodied carbon reduction pledges

Examples of EC reduction pledges for buildings industry stakeholders:

SECTOR	AUTHOR	ROADMAP	TARGET
Cement	World Business Council for Sustainable Development; Cement Sustainability Initiative	Low-Carbon Technology Roadmap for the Indian Cement Sector	50% emissions reductions by 2050
Cement, Concrete	Global Cement and Concrete Association	2050 Cement and Concrete Industry Roadmap for Net Zero Concrete	Net zero by 2050
Steel	International Energy Agency	https://www.iea.org/reports/iron-and-steel-technology-roadmap	Net zero by 2070
Steel	Mission Possible Partnership	https://missionpossiblepartnership.org/wp-content/uploads/2022/09/Making-Net-Zero-Steel-possible.pdf	Net zero by 2050

e. Developer and corporate building owner commitments

Examples of building owner commitments that include EC reductions:

SECTOR	FRAMEWORK	COMMITMENT
Architecture	2030 Challenge for EC	65% EC reduction by 2030, 100% by 2040
Architecture/Buildings Industry	World Green Building Council's Advancing Net Zero programme	40% EC reduction by 2030, 100% by 2050
Structural Engineers	SE2050	Net-zero EC by 2050
Mechanical Engineers	MEP2040	Net-zero EC by 2040
Government	C40 Clean Construction Declaration	50% EC reduction by 2030

f. Policies and institutional framework governing embodied carbon reduction in cement, concrete, and steel in India

DEVELOPER/OWNER	COMMITMENT
Lodha	Operational net-zero carbon by 2035, supply chain net-zero emissions by 2050
Lendlease	Net-zero carbon by 2040, including supply chain emissions
Kilroy	50% EC reduction by 2050
Amazon	Net-zero carbon by 2040, including supply chain emissions
Barclays	Net-zero carbon by 2050, including supply chain emissions
Hewlett Packard	Net-zero carbon by 2040, including supply chain emissions
HSBC	Net-zero carbon by 2030, including supply chain emissions
Microsoft	Carbon negative by 2030, including supply chain emissions

Cement, concrete and steel are the major sectors of the Indian economy, with the majority of these products used in construction. The Government of India has spearheaded numerous national and state programmes while participating in global initiatives to increase the demand for low-EC cement, concrete, and steel products and advance decarbonisation in these sectors. The table on the next page outlines the policies and programmes that play a role in shaping the manufacture and procurement of these materials.

TABLE 4.1 Government of India's National and International Initiatives

INITIATIVE	DESCRIPTION (RELEVANT TO EC)
India's NDC	• By 2030: Achieve 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources. • By 2030: Reduce emissions intensity of India's gross domestic product (GDP) by 45% from that in 2005. • By 2070: Achieve net-zero emissions.

Clean Energy Ministerial (CEM) and Industrial Deep Decarbonisation Initiative (IDDI)	• As a member of CEM, India is committed to IDDI's goals to stimulate global demand for low-carbon industrial materials by undertaking the following:
	  • Encouraging the government and private sector to purchase low-carbon steel and cement.
	  • Sourcing and sharing data for common standards and targets.

Smart Cities Mission and Climate Smart Cities Assessment Framework	• The Smart Cities Mission drives economic growth through sustainable development. • The Climate Smart Cities Assessment Framework outlines a climate-sensitive approach to urban planning, including the promotion of green buildings defined by rating systems such as Leadership in Energy and Environmental Design (LEED) that include EC reduction strategies.
National building-energy codes for commercial and residential buildings — Bureau of Energy Efficiency (BEE) — under the Ministry of Power	• The Energy Conservation Building Code (ECBC) — launched in 2007 and updated in 2017 and 2021 — optimises energy savings, keeping in mind occupant comfort and life-cycle cost-effectiveness to achieve energy neutrality in commercial buildings. • Eco-Niwas Samhita (ENS), i.e., the Energy Conservation Building Code for Residential Buildings, was launched in 2018 and encourages the adoption of passive design principles and strategies and careful material selection to enhance thermal comfort and energy efficiency. ENS states that the embodied energy of building materials and structural systems will be considered in future revisions. • Green building rating systems such as Green Rating for Integrated Habitat Assessment (GRIHA), LEED, and Indian Green Building Council encourage local sourcing and usage of sustainable building materials, waste materials, and SCM in construction.
National Green Hydrogen Mission	• Develop green hydrogen production capacity and make India a leading global producer and supplier of green hydrogen. • Create jobs and attract investment and business opportunities for the industry. • Support R&D projects.
National Steel Policy (2017)	• Promotes electric steelmaking and other technologies to bring down the use of coking coal in steel production and reduce GHG emissions.

Energy Conservation Amendment Bill (2022)	• Facilitate the achievement of India's NDC goals by promoting energy efficiency and conservation across equipment, buildings, appliances, and industries. The bill includes the following actions:
	  • Mandating the use of non-fossil fuel energy sources in industries such as steel and cement.
	  • Directing the central government to specify a carbon credit trading scheme.
	  • Providing an energy conservation and sustainable building code.

Perform, Achieve, and Trade scheme	• Established by the National Mission for Enhanced Energy Efficiency to reduce specific energy consumption in energy-intensive industries, including cement and steel. Includes certification of excess energy savings, which can be traded to enhance the cost-effectiveness of energy reduction.
GreenPro EcoLabel	• Developed by the Confederation of Indian Industry, this green labelling programme for environmentally preferable consumer products includes cement, concrete, and steel products.
Global Housing Technology Challenge	• The Global Housing Technology Challenge – India (GHTC-India) is an initiative by the Ministry of Housing and Urban Affairs to identify and mainstream innovative construction technologies that are sustainable, green, and disaster resilient. • By promoting the use of alternative materials and methods that have low EC, GHTC-India aims to reduce the environmental impact of housing construction and contribute to global efforts to mitigate climate change.
RACHNA	• The Resilient Affordable Comfortable Housing through National Action (RACHNA) initiative under GHTC-India creates awareness and capacity building among various stakeholders such as engineers, architects, contractors, builders, students, and others on the use of alternative materials and methods that have low EC.

At the 26th Conference of the Parties (COP26) in November 2021, India announced its commitment to achieving net-zero emissions by 2070 and later set an interim goal to reduce the emissions intensity of the country's GDP by 45% from that in 2005 by 2030. With the progress in urbanisation and carbon emissions from the building industry expected to nearly quadruple, it is necessary to transform India's buildings sector to reach these goals. Focused and immediate attention on cement, concrete, and steel materials, which are responsible for a large share of EC emissions in buildings, is needed to catalyse the market for zero-carbon construction.

CHAPTER 5

Fanning the Future

INTRODUCTION AND BACKGROUND

Climate change is driving an increase in global temperatures, leading to frequent and intense heatwaves.[1] The highest recorded temperature on the Earth in recent years was noted on 5 July 2023, illustrating the escalating global concern. India, with its diverse geographical terrain from the high-altitude Himalayas to the coastal regions, experiences varying climatic conditions. However, extreme heat is a common denominator across most of the country. As per the Indian Meteorological Department, India's average temperatures have been rising steadily, with summer-like conditions for almost eight months a year. Furthermore, climate models suggest that heatwaves in India are likely to become more frequent and severe due to global warming, leading to increased health risks and strain on the energy grid.[2]

India, as one of the most populous countries in the world, is particularly vulnerable to the escalating crisis of global warming. Simultaneously, India's ambition to become a trillion-dollar economy necessitates rapid urbanisation and development. While this signifies progress, it brings forth considerable challenges. One of the primary concerns is accommodating the rising urban population, a direct result of rural-to-urban migration. Even if the housing shortage is addressed, a secondary, equally significant challenge surfaces: managing the exponential surge in energy demand from newly populated urban households.

People in densely populated urban areas often experience the urban heat island effect, which leads to a multi-fold increase in the cooling requirement. Cooling needs account for nearly 60% of the energy demand in residential buildings.[3] These will intensify with rising incidence of heatwaves, potentially overburdening the already strained energy infrastructure.[4] India's cooling demand is expected to go up almost 11 fold by 2037, and the maximum share (an around 8-fold increase from that in 2017) is foreseen to be held by space cooling in the built environment.[5]

Thus, the interconnected issues of heat stress and energy demand underscore urban India's complex challenges in climate change and explicitly ensure thermal comfort for a billion lives. This necessitates identifying sustainable and energy-efficient solutions for the masses to meet the rising cooling demand for India's socio-economic development and safeguarding the well-being of its vast population.

In this context, fans have evolved from mere comfort appliances to indispensable necessities in every Indian household. Their overarching significance in Indian families is multifaceted. As an economical, accessible and effective solution to the prevailing high temperatures, fans are essential in mitigating heat-related discomfort. This is regardless of the socio-economic status and true for rural to urban locales and various income brackets.

Fans are utilised in over 95% of the households, with more than one per household.[6] This highlights their crucial role in ensuring sufficient air circulation and maintaining a basic standard of living. The widespread use of fans compared with costlier cooling devices such as air conditioners indicates their cost-effectiveness, operational efficiency and indispensability.

In 2017, the stock of around 450 million fans were estimated to contribute approximately 30% (41TWh) of the overall projected space cooling energy consumption (135TWh). This stock is expected to double by 2037, possibly leading to significant coincidental peak energy demand in the BAU scenario of installing fans with high wattages.

Thus, fans become a critical intervention that can be mobilised with less effort and reap high energy savings impact to meet the net-zero commitments and reduce operational energy consumption of buildings and homes.

FAN ECOSYSTEM

The primary function of a ceiling fan is to ensure air circulation. Fan blades rotate and push air downward, creating a breeze that moves across the skin of the people in the room and enhancing the evaporative rate. This air movement can make the room cooler than it is, leading to improved thermal comfort for occupants. This works even at more ambient temperatures, but the cooling effect may be reduced in extreme humidity as the moisture content in the air is already elevated, thus reducing the overall evaporation rate of people's skin.[7]

As fans are existent in each Indian household, their operation differs considering the socio-economic and environmental conditions.

a. **Individual operation:** Most fans in Indian households are operated manually using a regulator that can usually be set to control speed. Some fans also have a pull cord attached for speed control. With technological advancement, regulators are being replaced by remotes or IoT-based smart controllers. Manual operation is pervasive in low-income households, whereas remote- or IoT-based smart controllers are picking up in middle- and high-income families.

b. **Combination with air conditioning:** In households with air conditioning, fans are often used with air conditioners to circulate the cool air more effectively throughout the room, allowing air conditioners to be set at a high temperatures for the same level of comfort. According to a household survey, almost 55% of the end users operate fans with air conditioners.[8]

Key factors affecting fan performance: The key metric of a fan's performance is the service value, which is the ratio of air delivery in meter cubes per minute and power consumption. It depends on two parameters:

a. **Air circulation and flow:** Ceiling fans come in various blade sizes such as 900 mm, 1200 mm, 1400 mm and others to suit different room sizes. The airflow and circulation differ depending on the blade size. The higher the fan sweep size, the more is the airflow within the space. Airflow and circulation are also dependent parameters of blade design. With a rise in sweep size, service value is also expected to increase considering the proportional increase in airflow and circulation and the blade's sweep size.

b. **Power consumption:** Power consumed by a ceiling fan in an hour at full speed is considered to be a measure of the service value.

The Bureau of Energy Efficiency (BEE) launched the following mandatory star labelling schedule for fans effective from 1 July 2022 to 31 December 2024, as shown in Exhibit 5.1

EXHIBIT 5.1 **STAR RATING OF CEILING FANS AND THEIR SERVICE VALUES**

STAR RATING*	SERVICE VALUE FOR BLADE SIZES	
	1,200 MM AND ABOVE	LESS THAN 1,200 MM
1	4.0–4.5	3.1–3.6
2	4.0–5.0	3.6–4.1
3	5.0–5.5	4.1–4.6
4	5.5–6.0	4.6–5.1
5	6.0 and above	5.1 and above

*The fan performance is tested in conformance to ISO 374:1979

FAN ENERGY NEXUS

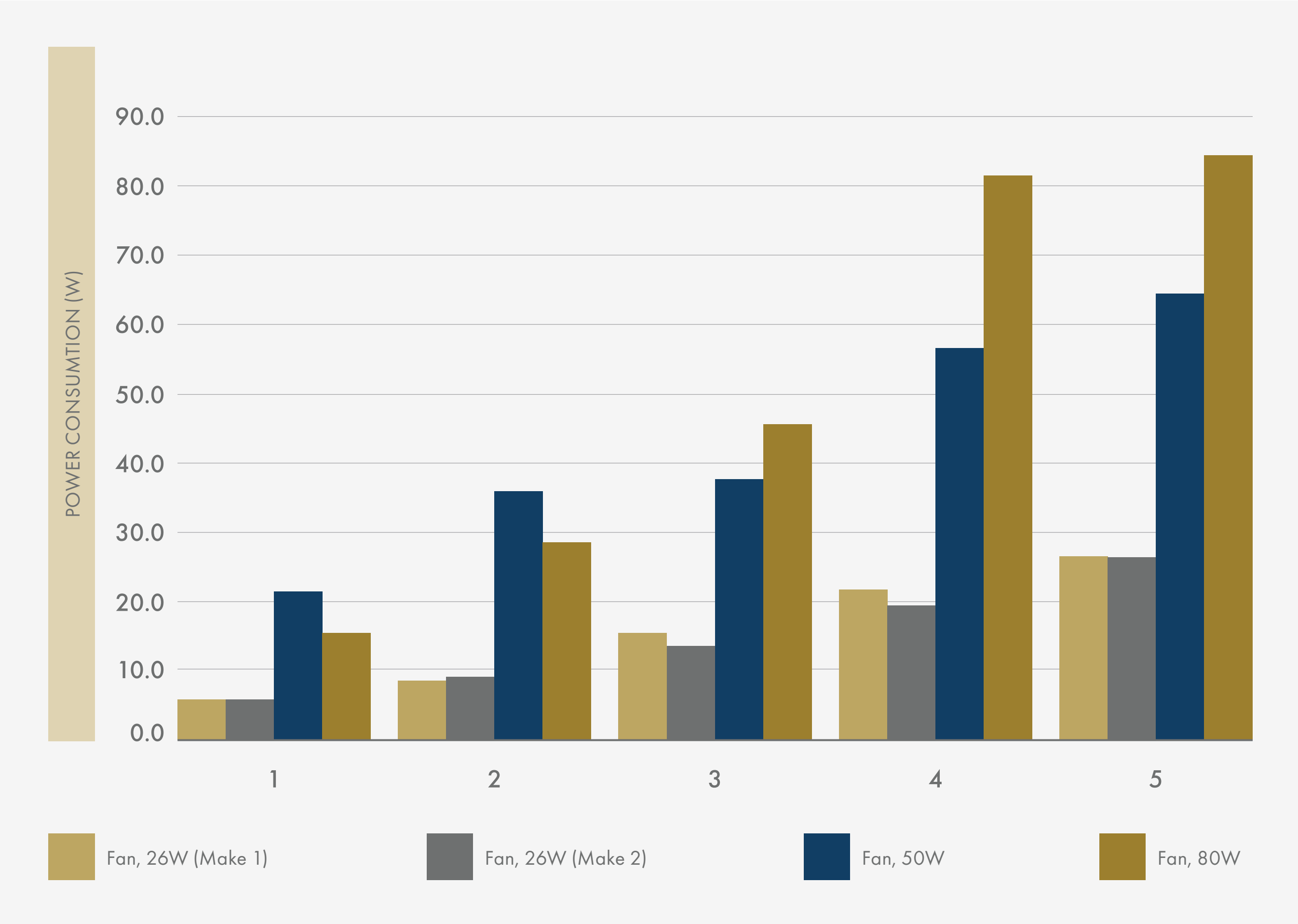
Today's best available technology (BAT) is brushless direct current (BLDC) fan, which consumes as low as 24W. A real-world comparative study done at Palava evaluated 26W, 50W and 80W ceiling fans to establish the fan energy nexus. Four rooms in a school were selected were selected for the analysis, each with four identical ceiling fans of different power ratings— 26W, 50W and 80W. Two of the rooms were fitted with 26W ceiling fans each. The fans were operated at various speeds using fan speed regulator with a range from 1 to 5, and instantaneous power and energy consumption were measured over 24 hours. The findings are presented in the Exhibit 5.2 below:

EXHIBIT 5.2 **POWER AND ENERGY CONSUMPTION OF VARIOUS CEILING FANS**

ROOM NO.	RATED POWER	MEASUREMENTS	SPEED 1	SPEED 2	SPEED 3	SPEED 4	SPEED 5
1	26W	Power, W	5.8	8.3	15	21.1	25.9
		Energy, Wh (24 hours)	139.2	199.2	360	506.4	621.6
2	50W	Power, W	20.8	37.3	37.4	63.1	61.1
		Energy, Wh (24 hours)	499.2	895.2	897.6	1,514.4	1,466.4
3	80W	Power, W	15.1	27.7	44.6	53.6	82.5
		Energy, Wh (24 hours)	362.4	664.8	1,070.4	1,286.4	1,980

The power consumed by a super-efficient (SE) BLDC ceiling fan at the lowest speed is 5.8W, which is at least three times more efficient than 50W and 80W ceiling fans at the lowest rates. The same trend is observed at the top speed. Exhibit 5.3 shows the instantaneous power consumption at various speed settings.

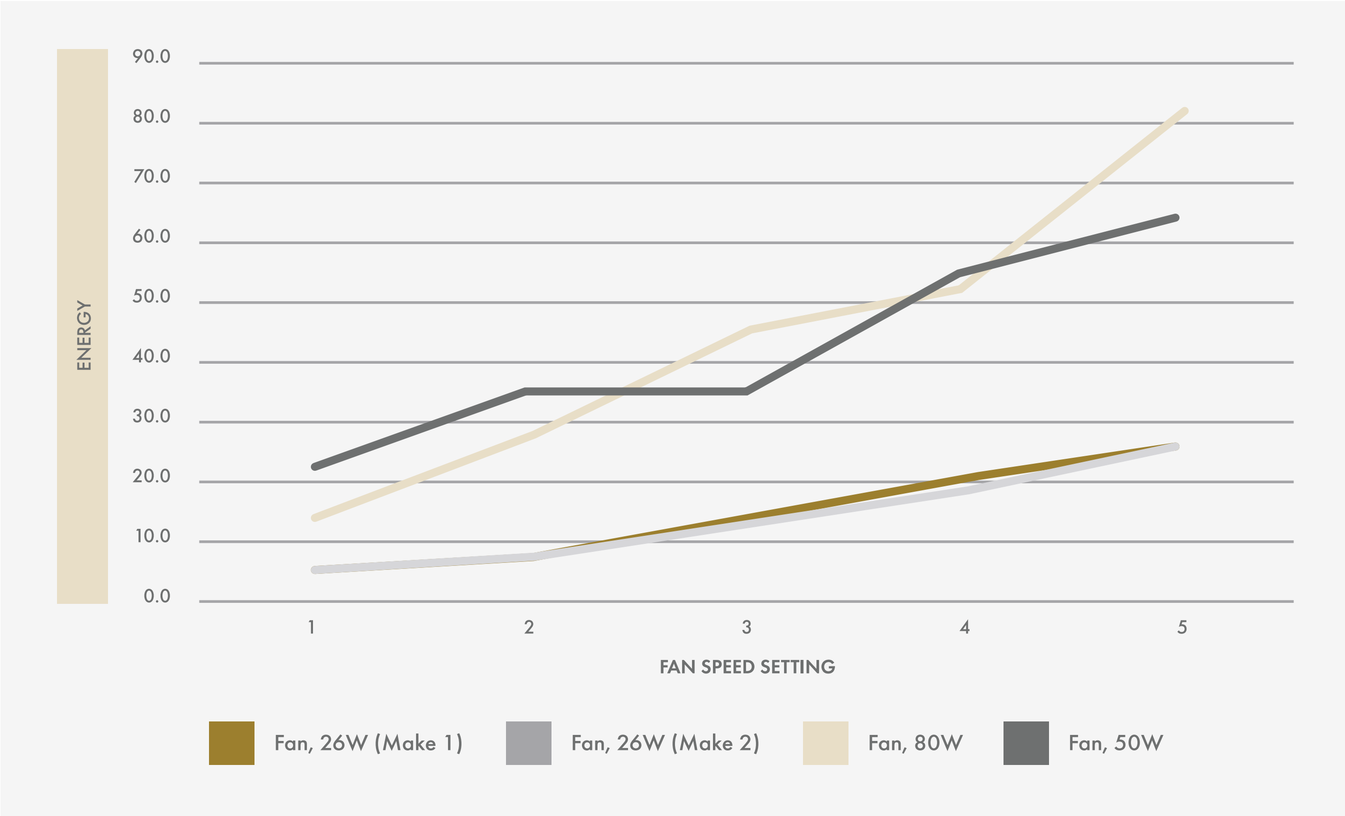
EXHIBIT 5.3 **ENERGY CONSUMPTION IN 24 HOURS AT DIFFERENT SPEED SETTINGS**



Source: Author's analysis

An SE 26W BLDC fan consumes hourly energy of less than 6Wh at the lowest speed, while an 80W conventional fan consumes 15 Wh. This could potentially lead to 66% energy savings and associated operational cost reduction. Similarly, an SE 26W BLDC fan consumes hourly energy of 25.6Wh at top speed compared with an 80W conventional ceiling fan consuming 82.5Wh as presented in Exhibit 5.4.

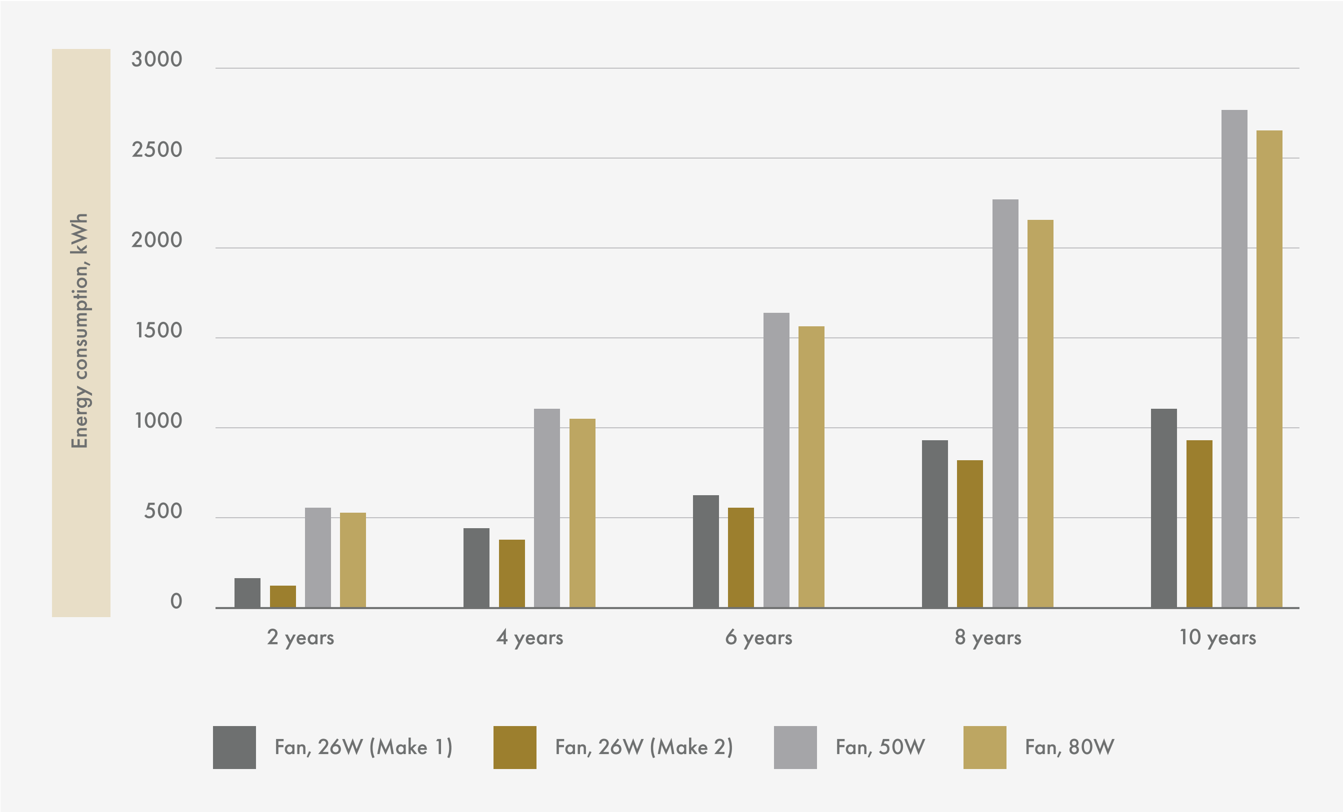
EXHIBIT 5.4 **ENERGY CONSUMPTION PATTERN ON DIFFERENT FAN SPEED SETTINGS**



Source: Author's analysis

Assuming the usual set speed for fans at 'speed 4' and 24-hour operations, the energy consumption was estimated for 10 years in Exhibit 5.5.

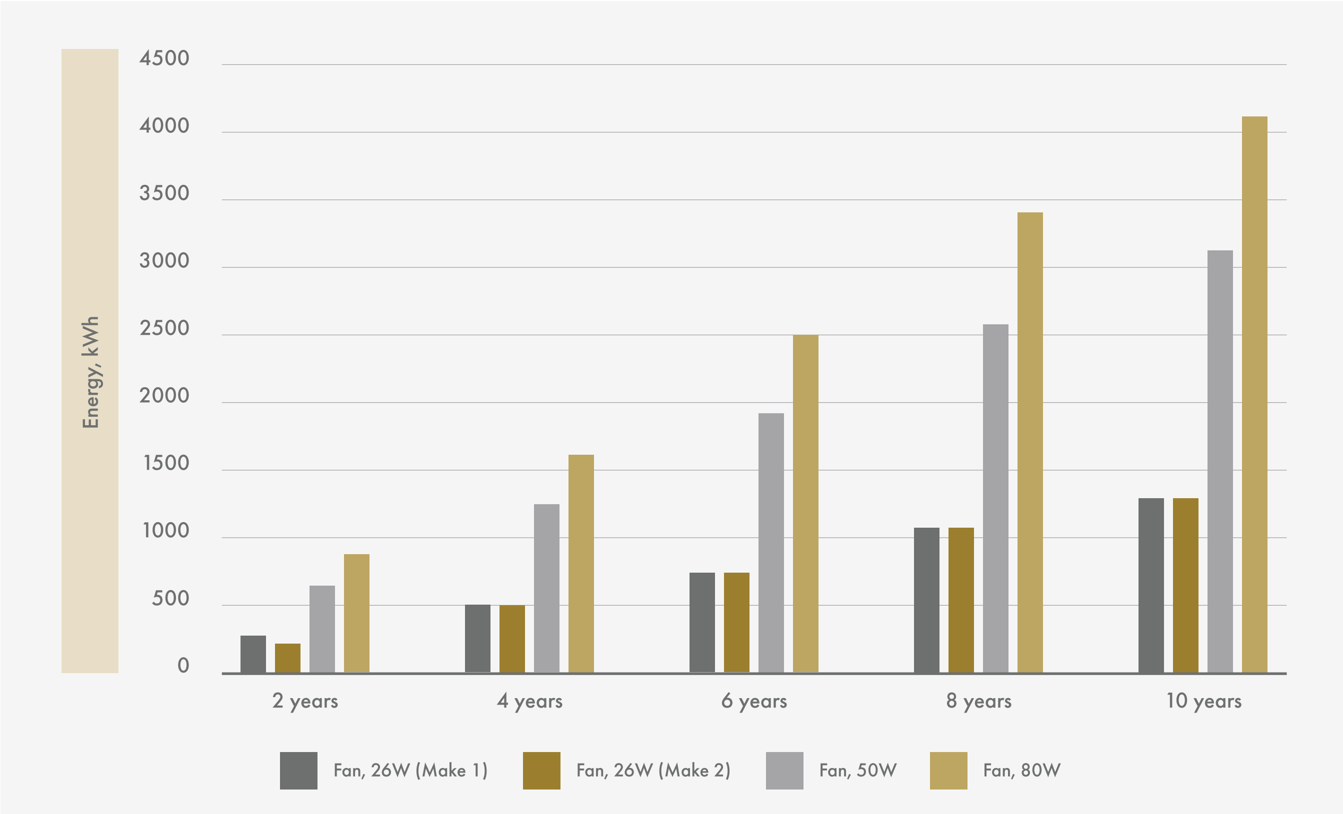
EXHIBIT 5.5 **CUMULATIVE ENERGY CONSUMPTION PROJECTIONS AT FAN SPEED 4**



Source: RMI Analysis

An SE 26W BLDC fan would consume three times less energy cumulatively in 10 years, which is approximately equivalent to 2,000 units, resulting in cost savings of approximately INR 20,000 (calculated at INR 10/kWh on average).

EXHIBIT 5.6 **CUMULATIVE ENERGY CONSUMPTION PROJECTIONS AT FAN SPEED 5**



Source: Author's analysis

In addition, projections were made for fans running at full speed i.e. 'speed 5'. The same trend was noted for a BLDC fan as in the case of 'speed 4', as can be seen in Exhibit 5.5 and Exhibit 5.6.

Life cycle cost of ceiling fan

The life cycle cost (LCC), also known as whole life costing, is a method to determine the total cost of ownership of a product or service. It includes all the costs associated with the product or service over its entire life cycle, from initial acquisition and installation to its use, maintenance and final disposal. The main components of LCC typically include the following:

1

Acquisition costs

These are associated with purchasing the product or service and could include the product cost and other costs associated with installation or initial setup.

2

Operating costs

These are associated with using the product or service and could include energy, maintenance, repair and other costs associated with the daily use of the product.

3

Maintenance and repair costs

These are associated with keeping the product or service in good working order and could include regular maintenance and repairs over the product's life.

4

End-of-life costs

These are associated with disposing of the product or service at the end of its useful life and could include costs associated with decommissioning, disposal or recycling.

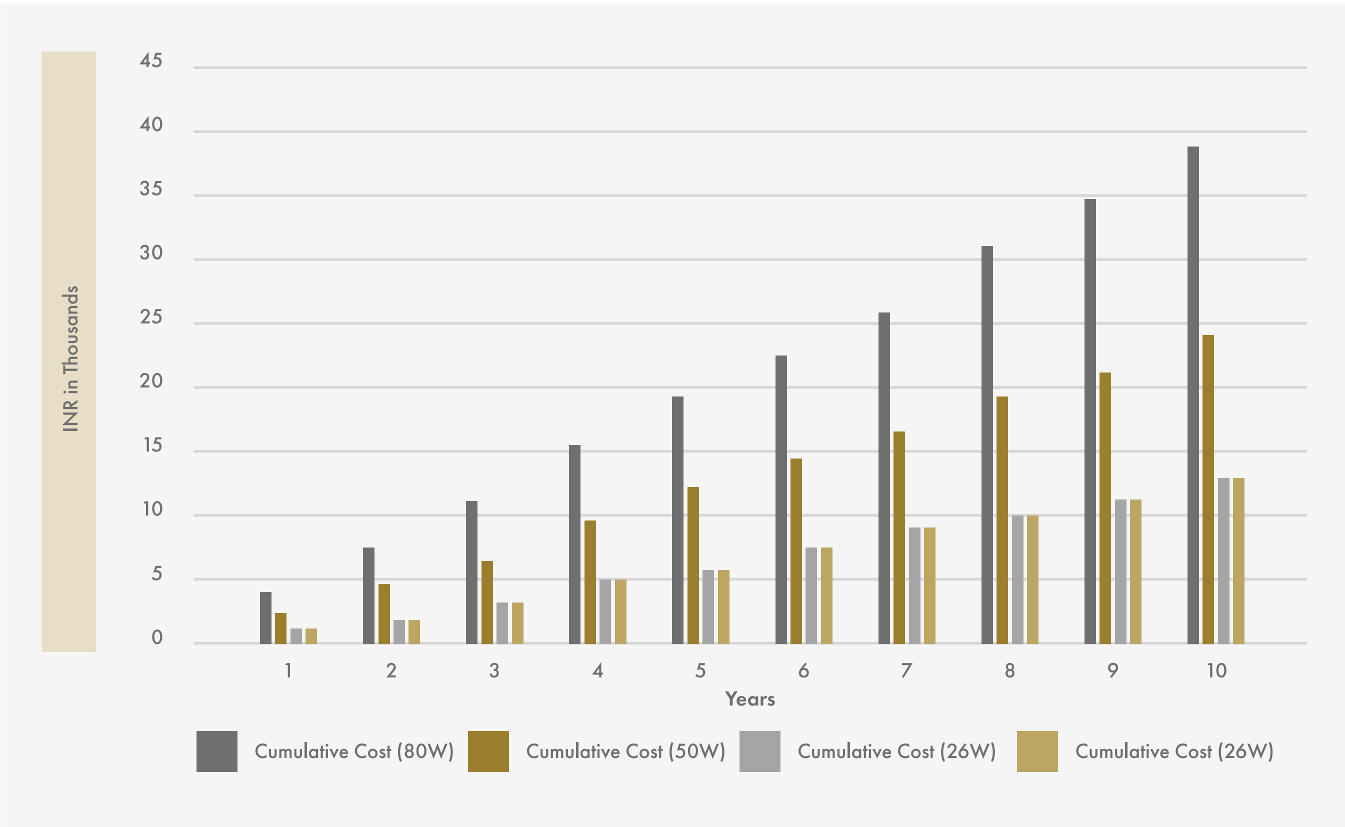
In the particular case of a ceiling fan, the overall lifespan is at least 12 to 15 years, with minimal or no maintenance or repair costs involved. Therefore, the only relevant components are the acquisition cost or capex and operating costs, that is, energy consumption in case of fans.

The following assumptions are made to estimate the lifecycle energy savings and costs:

- Operational hours: 16
- Operational speed: 5
- Lifespan of fan: 10 years

Exhibit 5.7 below shows the cumulative amount of savings over 10 years:

EXHIBIT 5.7 **CUMULATIVE COST OF FAN OPERATIONS**



The 26W BLDC fan payback period was approximately 10 months against the 80W model and 22 months (1 year 10 months) against the 50W model and is presented in Exhibit 5.8.

EXHIBIT 5.8 **LIFE CYCLE COST ANALYSIS OF CEILING FANS**

TYPE OF FAN	80W FAN	50W FAN	26W FAN
No. of fans	1	1	1
Average daily operational hours	16	16	16
No. of operational months	10	10	10
Total yearly operational hours	4,800	4,800	4,800
Annual energy consumption (kWh)	384	240	124.8
Average electricity unit usage rate	10	10	10
Annual price to consumer	3,840	2,400	1,248
Fan cost	1,300	1,600	2,200
Annual savings from BLDC fan compared with 80W fan			2,592
Payback period when compared with 80 W fan (Years)			**0.849**
Annual savings from BLDC fan compared with 50W fan			1,152
Payback period when compared with 50 W fan (Years)			**1.9**

CASE OF PALAVA CITY

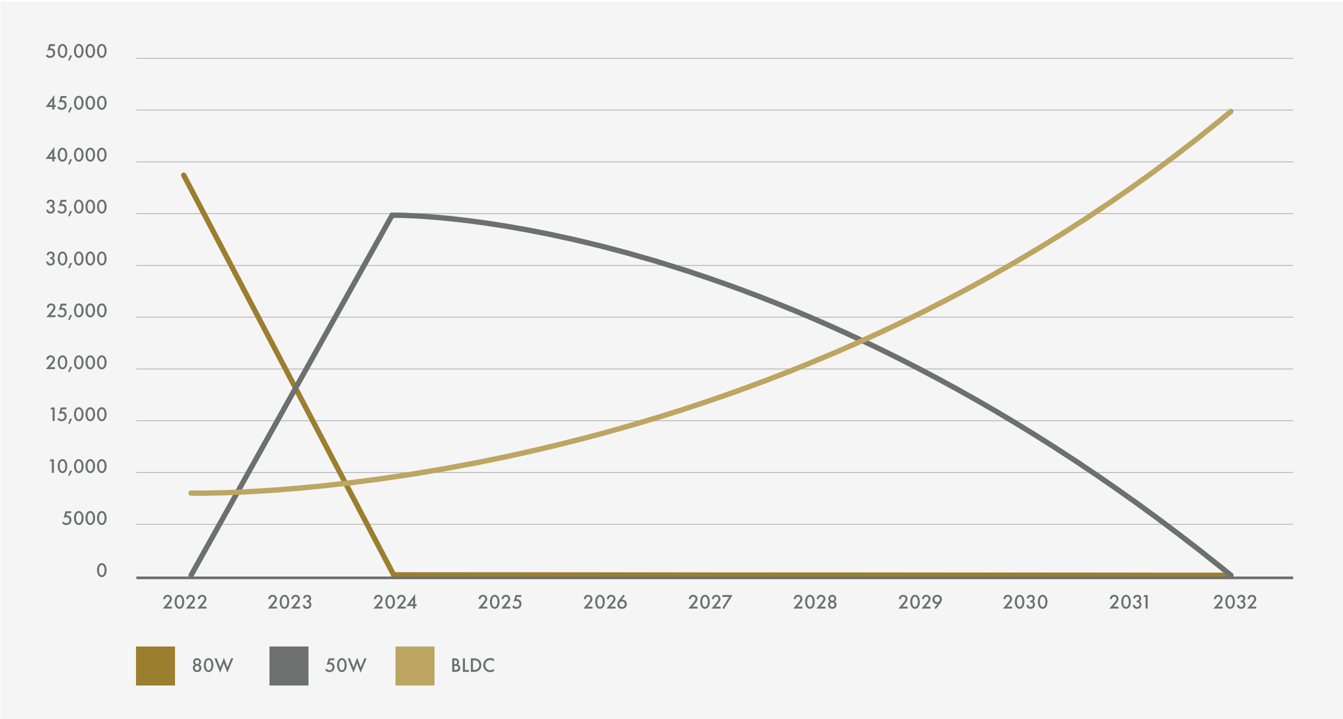
Currently, almost 24,000 (phase 1 and phase 2) flats have been delivered, and plans are to expand to around 250,000 flats that can host over a million people by 2035 are underway. A significant energy demand would arise from the cooling requirements of these units, and all end users are expected to get fans installed before occupying flats as these are new units. Therefore, fans would have a significant share in the city's cooling energy demand.

Data collected from more than 300 units showed 100% penetration of fans in the delivered units. Types of fans installed in these units varied in wattage— most were 80W fans and 15% households used BLDC fans. In addition, BEE has mandated the standard and labelling programme for fans. The annual sales of upcoming is presented in Exhibit 5.9, considering the following assumptions:

- Average number of fans per household: 3
- Annual number of households delivered in Palava: 15,000
- Annual new sales of fans: around 45,000
- Share of different types of fans based on wattage in 2023: 43%, 40% and 18% for 80W, 50W and BLDC fans, respectively

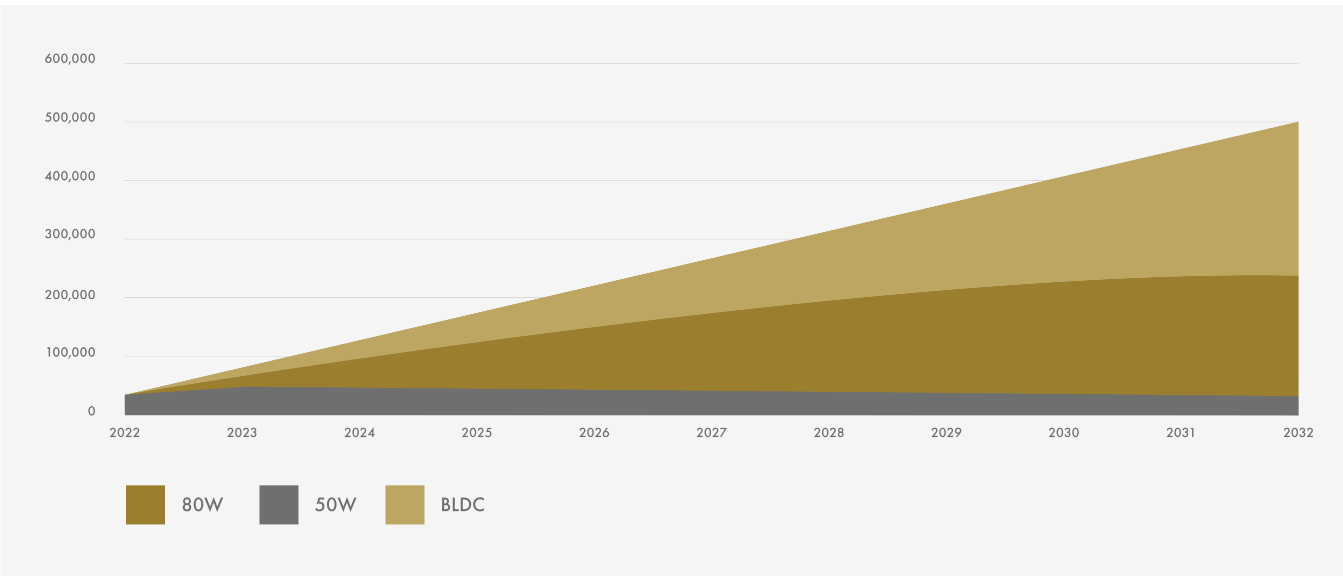
The share of new fan sales is presented in the figure below:

EXHIBIT 5.9 **NEW FAN SALE IN BAU SCENARIO – BAU UNTIL 2032**



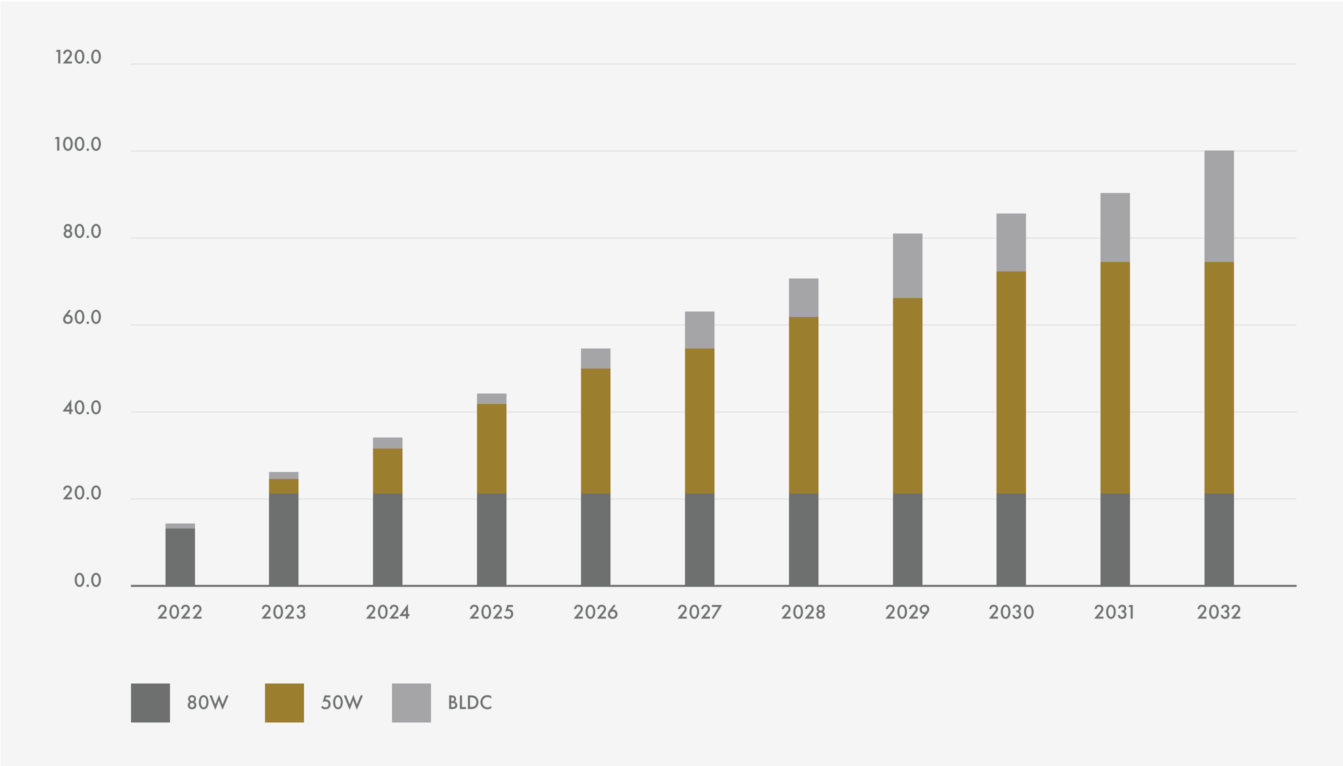
The resultant stock trend in Palava in the BAU scenario is shown in the Exhibit 5.10:

EXHIBIT 5.10 **FAN STOCK IN PALAVA – BAU UNTIL 2032**



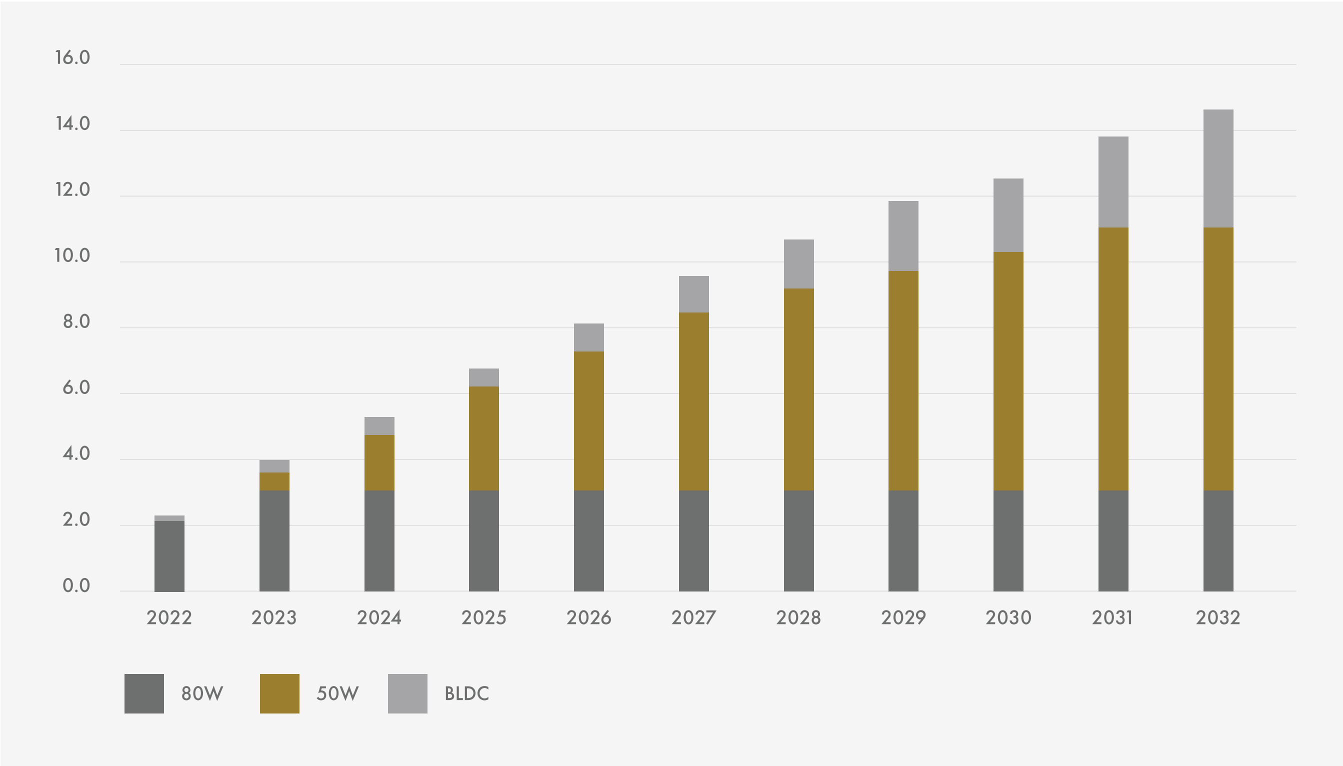
In the BAU scenario, the overall resultant fan stock in the next 10 years is expected to be around 500,000 fans, with more than 50% being in the 50W and 80W categories and consuming at least double the energy of a BLDC fan and locking-in inefficiency for another decade is presented in Exhibit 5.11:

EXHIBIT 5.11 **PROJECTED ENERGY CONSUMPTION (GWh) – BAU SCENARIO**



If the BAU scenario continues, Palava would consume more than 100GWh from only fans by the end of 2035. The overall energy consumed cumulatively from 80W and 40W fans is expected to be around 72% of the estimated overall energy consumption of fans. In addition, an overall peak demand arises from fans, as shown in the Exhibit 5.12 below:

EXHIBIT 5.12 **PEAK DEMAND FROM FANS – BAU**



A substantial peak load of around 14.7MW would arise from these fans, considering only approximately 70% work at a particular time. It is imperative to accelerate the uptake of BLDC fans in Palava City and ensure that inefficiencies do not get locked in as they provide appropriate ventilation and are the cooling equipment chosen by the masses. Therefore, it is necessary to understand the barriers to adopting SE fans in Palava City.

BARRIERS TO ADOPTION OF SE FANS

Even after evidential benefits, the uptake of SE fans is limited. The barriers to the adoption of SE or BLDC fans in this context can be categorised into several key areas:

1

Cost

BLDC fans typically have a higher upfront cost than conventional fans due to the advanced technology they use. This can deter potential buyers, especially in cost-sensitive markets as there is a cost increment of around 40% compared with a 50W fan.

2

Awareness

Many consumers are unaware of the benefits of BLDC fans, such as energy efficiency and quiet operation, and may see no value in investing in these fans. In addition, some consumers perceive BLDC fans as more complex to install or operate than traditional fans. This perception, even if unfounded, can be a deterrent.

3

Resistance to change

People often resist changing their habits, including their purchase habits. If they have been using traditional fans for many years, they may be reluctant to switch to a new type of fan. People attach intrinsic and sentimental possession to products if given as gifts on special occasions or related to specific memories (e.g. gifted during weddings or belonging to ancestors).

4

Availability

BLDC fans may not be as readily available as traditional fans in some markets. Limited availability in local stores due to less demand also hinders their adoption.

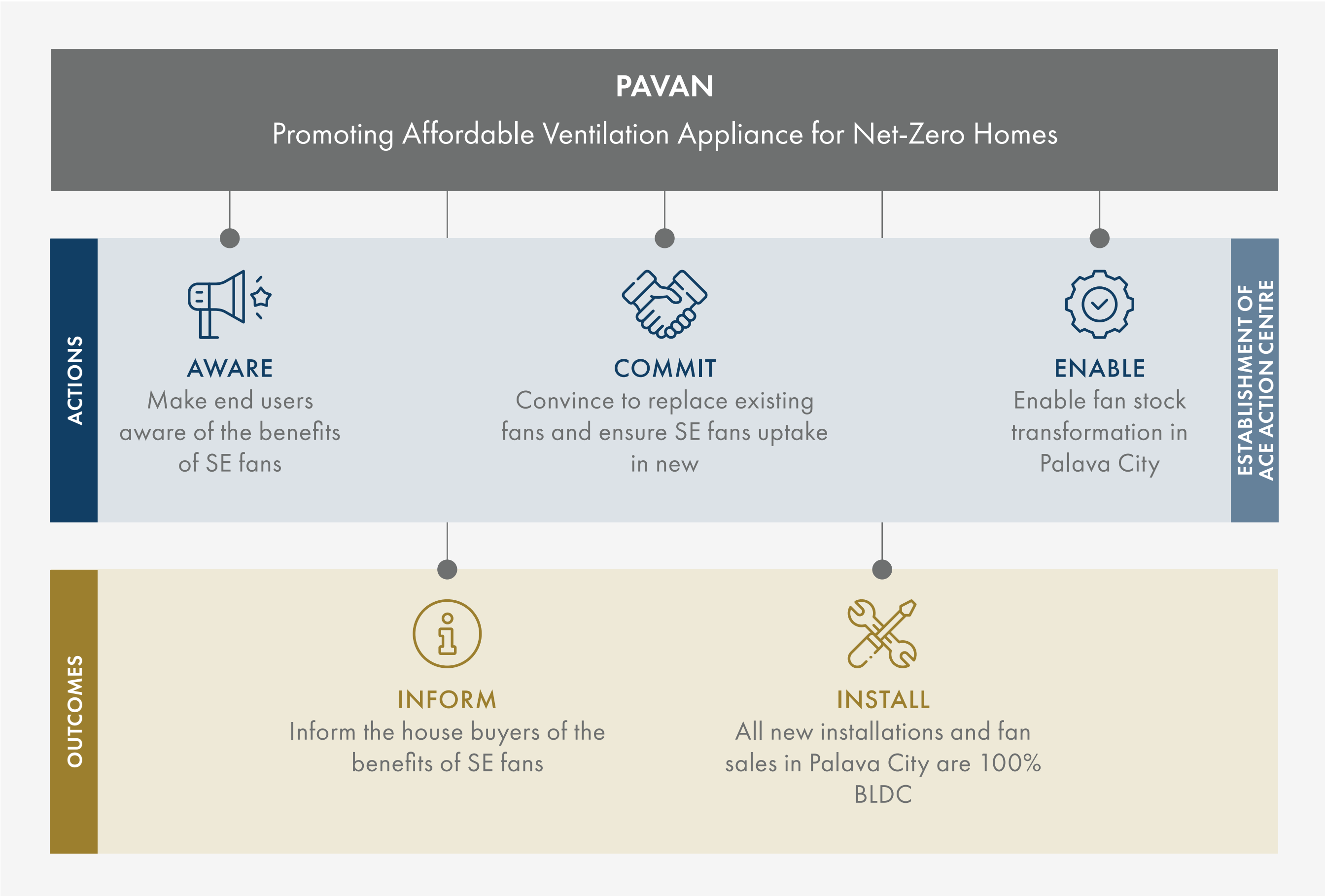
5

Long replacement cycles

Fans are not frequently replaced appliances. Therefore, even if a consumer is aware of and interested in BLDC fans, they may not have the opportunity to purchase one until their existing fan needs to be replaced.

Addressing these barriers requires a multifaceted approach, including consumer education, increasing product availability, providing financial incentives and informing on the long-term benefits of energy efficiency. Under the large ambit of achieving net zero by 2035, Lodha has come up with several initiatives. A low-effort, high-impact intervention that can help curtail rising energy demand in existing and future group developments is the uptake of SE fans. It will require overcoming the barriers highlighted above as the development activities on site are underway and will continue until 2035 to establish a community of a million families. However, a part of the city is already constructed and delivered. Therefore, almost all end users are projected to have installed new fans within the last three years, as the units are usually sold without the fans. Thus, to prevent locking in inefficiencies, end users need to be convinced to adopt SE fans. Lodha, under the Urban Accelerator, plans to launch **Mission PAVAN (Promoting Affordable Ventilation Appliance for the Net-zero homes)** with support from RMI India Foundation. Mission PAVAN would take a two-pronged approach, one for existing buildings and another for new buildings, as showcased in the Exhibit 5.13 below:

EXHIBIT 5.13 **FRAMEWORK FOR ESTABLISHMENT OF ACE ACTION CENTRE**



Launch of Mission PAVAN

As per the social sciences of material possession attachment, people attach intrinsic value with certain commodities. This is also noted for ceiling fans when they are either considered heritage of ancestors or received as gifts. A more nuanced approach towards engagement with stakeholders and convincing end users of the benefits they accrue over time are essential. However, most of the Palava township was developed in the last seven to ten years, with only a small part of it being fit for occupancy by end users who may still be in the deciding phase of equipment installation. Thus, the window of opportunity is small as residents would soon start to move into the new households being delivered.

The ACE action centre to be established on the ground would target end users to accelerate fan market transformation and achieve the change five years before the BAU scenario. It would enable the replacement of inefficient installed stock in at least 50% of the existing households and ensure the entire new sales to be BLDC fans by 2027.

ACTION PLAN

The ACE action centre established by Net Zero Urban Accelerator would work on three prime actions to help end users with informed decision-making: awareness, committing demand and enabling on-site deployment for end users as presented in Exhibit 5.14.

EXHIBIT 5.14 **PILLARS OF ACE ACTION CENTRE**

ACTION 1 – AWARENESS

The ACE action centre would set up large awareness campaigns to change human behaviour and increase acceptance towards BLDC fans. It would include the following innovative approaches:

- **Setting up experience centres and kiosks** within the development, which can be easily done in areas of public assembly. It would ensure that the energy consumption is displayed and easily understandable by a non-expert in the field. A comparative fan from the minimum energy performance level should also be exhibited to let end users understand the impact of using energy-efficient fans over the years.

- **Running consumer campaigns with RWAs**, such as quizzes on energy efficiency, should be designed for the participation of community stakeholders and target women, youth and children to help influence consumer choices.

- **Designing behavioural change campaigns**, including developing informational material such as flyers and signing up messaging strategies targeting consumer behaviour. The strategy could include an update on the number of installations to create a buzz and sense of urgency within the community. Taking into account the historical marketing strategy of the fear of missing out, the community will react to purchase more fans, enabling accelerated uptake of BLDC fans in Palava.

- **Setting up fans in sample/demo flats in Palava**, standardising the pitch narrative to showcase the importance of SE fans to prospective buyers, gauging their reactions to assess the acceptance of the installation and understanding concerns regarding aesthetics, if any.

ACTION 2 – COMMITMENT

The ACE action centre would aim at convincing end users to create a sizeable demand for industry players through awareness and interactions.

- **Incentive needs assessment**, interacting with community stakeholders and end users to assess the required motivation for enabling accelerated replacements.

- **Commitment assessment** to assess the commitments that can be made by end users through enrolment forms. This will help understand the community sentiment about pricing preferences that end users are ready to pay. Leveraging this information, fan pricing and the operation of replacements can be negotiated with industry stakeholders.

ACTION 3 – ENABLE

Based on the outcomes of the previous two pillars, the centre could establish a direct interlinkage between end users and industry players for accelerated on-ground deployment.

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- **Negotiations with fan manufacturers** based on the commitment from end users to arrive at a reduced cost and agreement on other terms and conditions regarding the replacement scheme created for the Palava community.

- **Partnership between ACE centre and national aggregator agencies.** By sharing the commitments from Palava City end users and creating a pipeline for deployment. It will also allow end users to access fans sourced at the national level at a subsidised rate.

- **Facilitation kiosk** that can act as a sale point and exchange between end users and industry players can be set up in the Palava premises for one year for up to three companies providing the best rates and agree to the consumer-centric terms and conditions set up by the ACE action centre.

- **Pre-installation of ceiling fans in new units:** Based on the results of pilots, the possibility of large-scale pre-fitment of fans can also be explored within the city. To enable the large-scale pre-fitment, new business models and access to different financing options such as climate finance and carbon markets can be explored.

The ACE action centre would be live for five years until 2027 and ensure on-ground implementation of activities related to the uptake of SE ceiling fans in Palava City. It would facilitate exchange between fan manufacturers and end users. In addition, the ACE centre will explore financing options for end users and establish business models that can help in scaling up the deployment.

EXPECTED OUTCOME AND IMPACT OF ACE ACTION CENTRE

Outcome 1: Inform

The ACE action centre would spread awareness about the benefits of BLDC fans across Palava City.

Outcome 2: Install

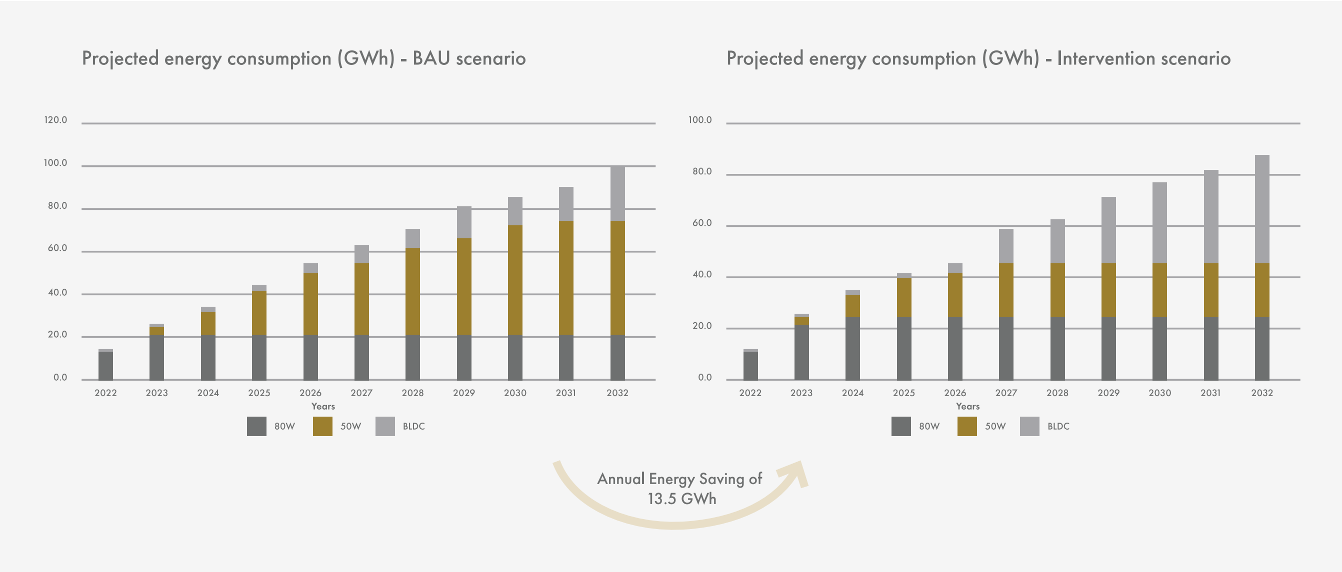
The ACE action centre would achieve 100% new sales of BLDC fans by 2027.

ANTICIPATED IMPACT

The ACE action centre would enable an accelerated uptake of BLDC fans in Palava City. Some of the measurable impact is as follows:

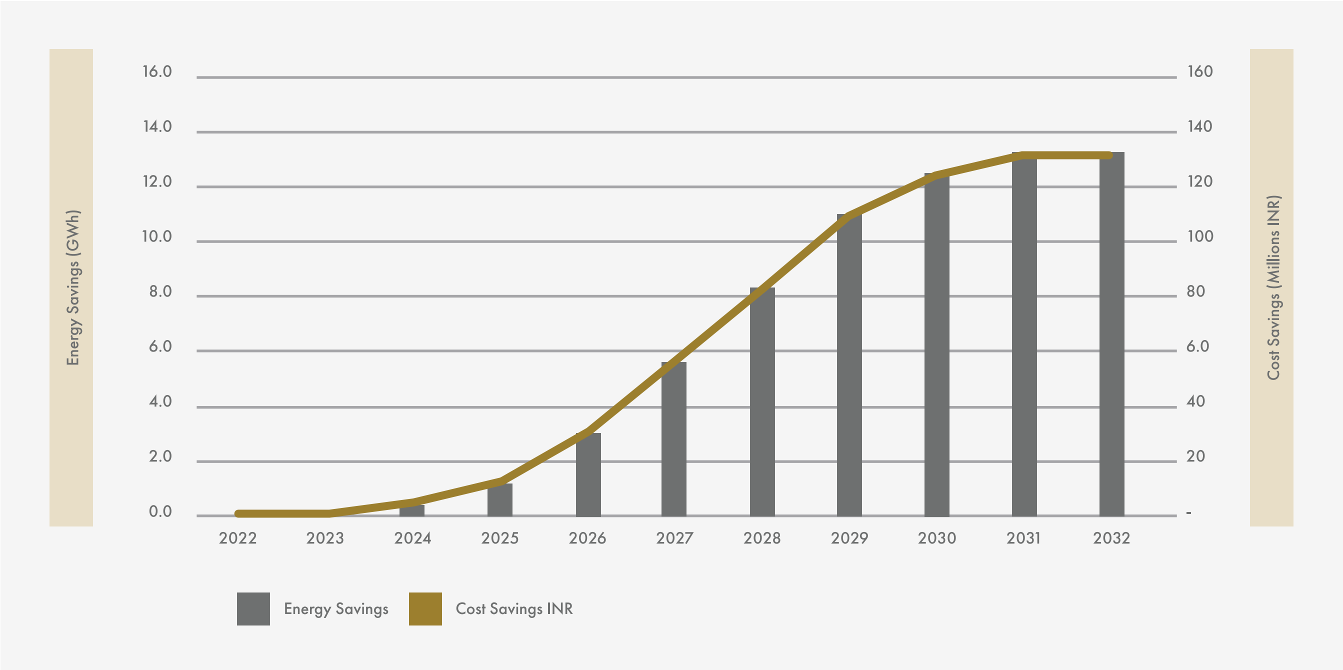
1. An annual energy savings of around 13GWh can be achieved by accelerating the transition to BLDC fans in Palava as presented in the Exhibit 5.15 below:

EXHIBIT 5.15 **ANNUAL ENERGY SAVINGS FROM ACCELERATED PENETRATION OF BLDC FANS**



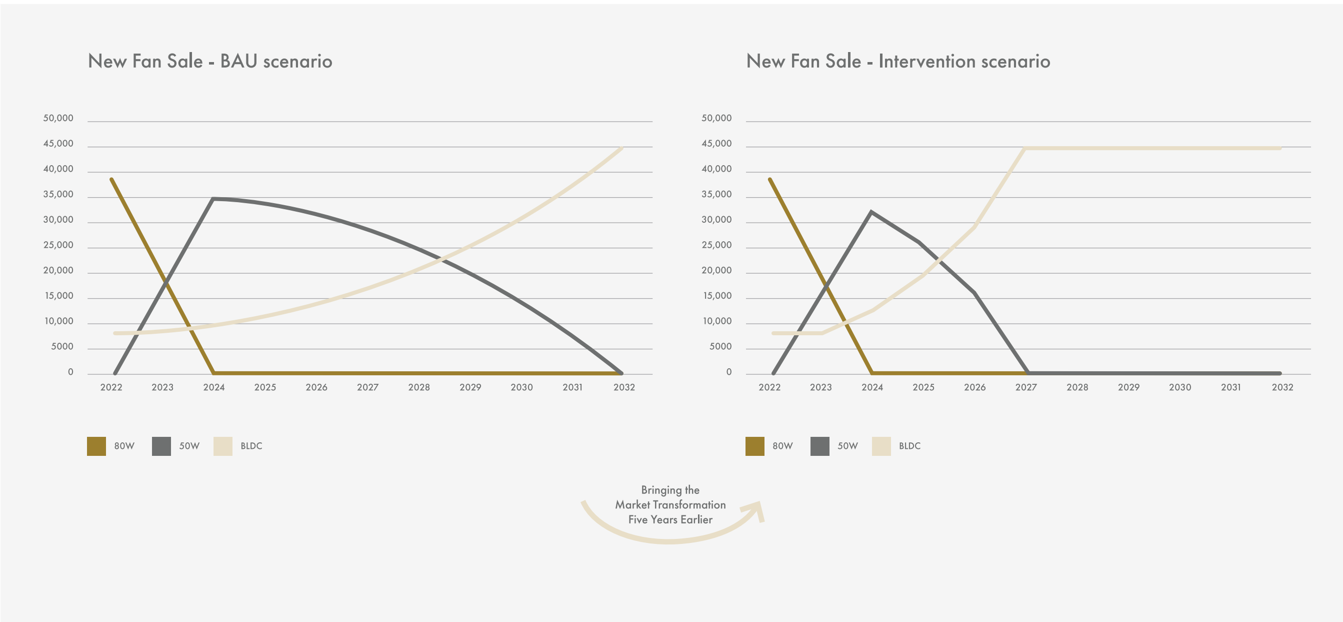
2. Besides annual energy savings, annual cost savings only from reduced energy consumption can accrue for over 130 million INR by the year 2032 as depicted in the Exhibit 5.16 overleaf.

EXHIBIT 5.16 **ENERGY COST NEXUS**



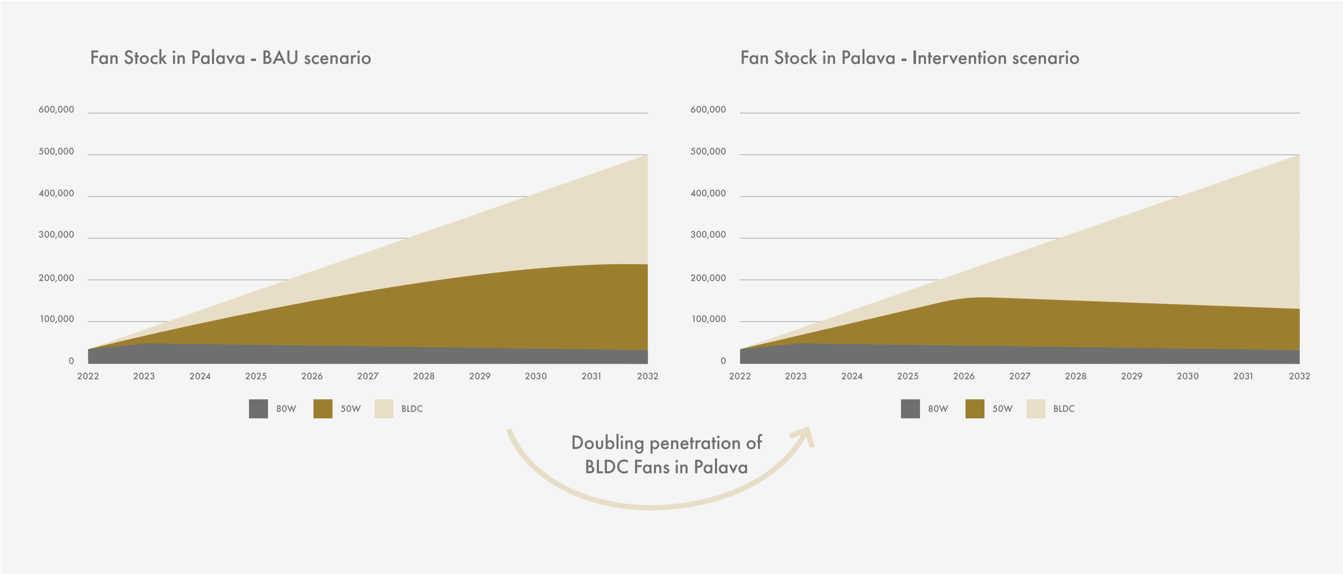
3. Compared to the BAU scenario, the market transformation and transition to BLDC technology can be achieved five years earlier as depicted in the Exhibit 5.17 below:

EXHIBIT 5.17 **ACCELERATING THE MARKET TRANSFORMATION**



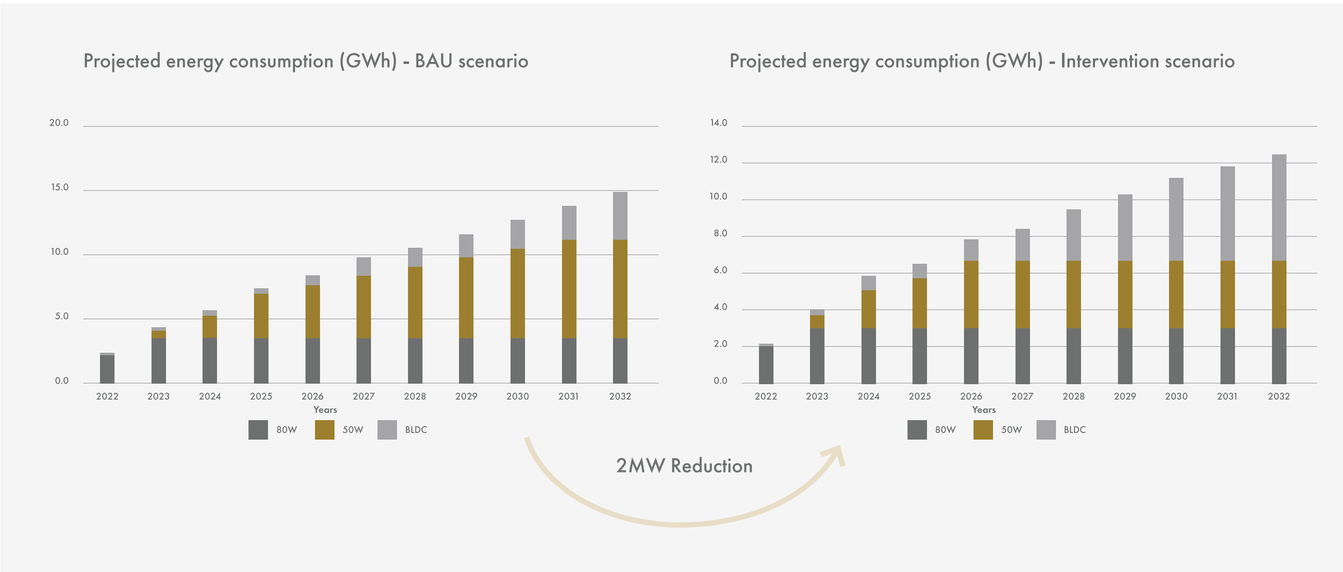
4. Compared to the BUA scenario, doubling the penetration of BLDC fans in Palava as depicted in the Exhibit 5.18 below:

EXHIBIT 5.18 **FAN STOCK PROJECTION IN PALAVA CITY**



5. In addition to the above mentioned benefits, peak demand reduction of 2MW is also expected to happen due to interventions made for accelerated uptake of ceiling fans in Palava as depicted in Exhibit 5.19 below:

EXHIBIT 5.19 **PEAK DEMAND REDUCTION PROJECTION FROM UPTAKE OF BLDC FANS**



In anticipation of the forthcoming launch of Mission PAVAN, several pivotal steps lie ahead as mentioned in the sections above. Establishing a baseline of the fans in Palava City will be the initial focus, providing a comprehensive overview of the existing infrastructure. Subsequent to this, the identification of effective behavioural strategies will be crucial to ensure that end-users are inclined towards the adoption of S.E. fans. Additionally, gauging the awareness and readiness of end-users about S.E. fans, discerning their willingness to transition, and pinpointing the price points that would encourage immediate acquisitions will be undertaken. The final stride in this phase will be to explore potential collaborations with national aggregator agencies, with a particular emphasis on entities like EESL. As the mission progresses, these steps will be instrumental in shaping a sustainable and net zero horizon for Palava City.

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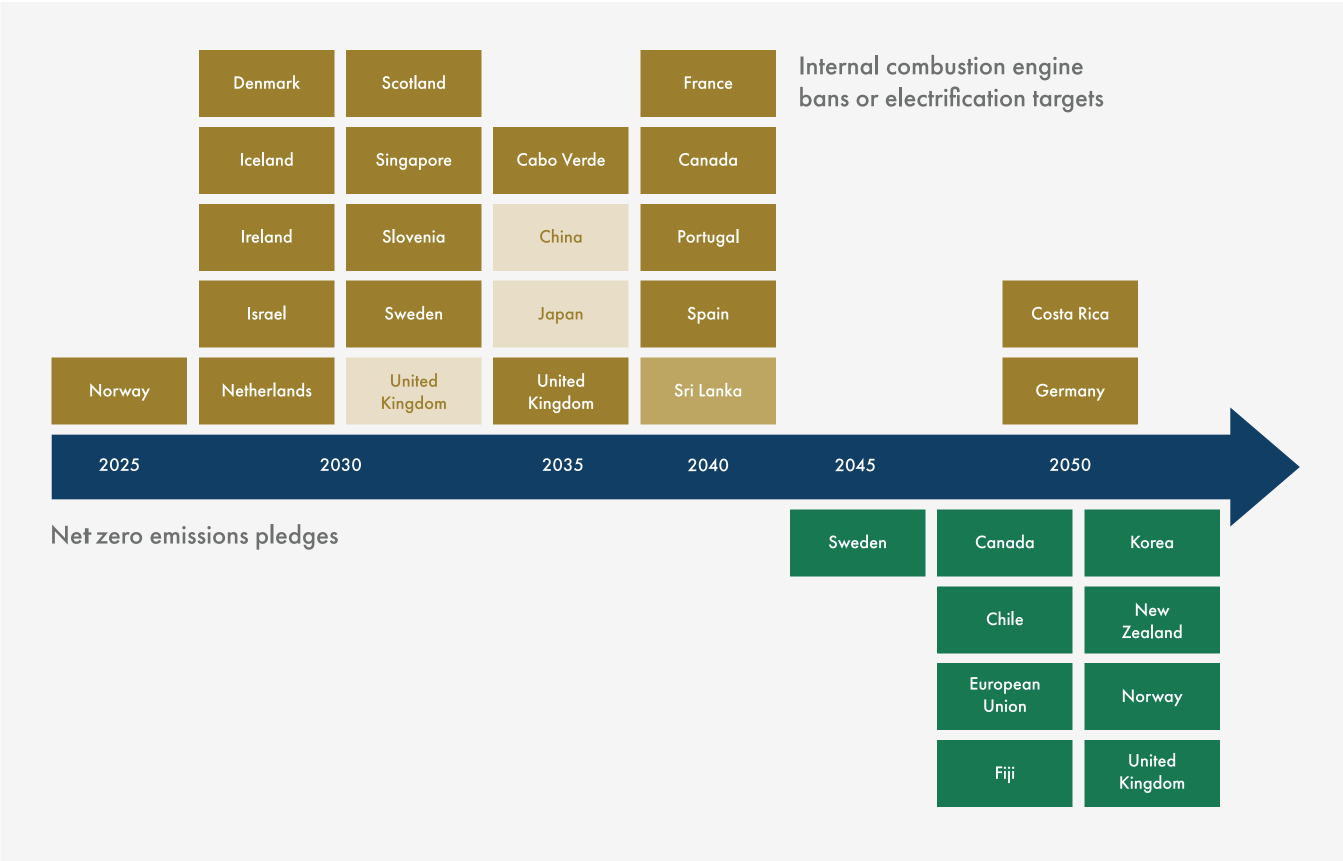
CHAPTER 6

Charging and Swapping Infrastructure Deployment: Needs Assessments, Challenges and Roadmap for Deployment in Palava Township

INTRODUCTION AND BACKGROUND

Climate change is one of the world's foremost challenges. Globally, the transport sector accounts for 23% of the total greenhouse gas (GHG) emissions responsible for climate change. Therefore, the decarbonisation of the transport sector by transitioning to a clean mobility future is a key goal of governments across the world. Exhibit 6.1 shows the transport decarbonisation and net-zero targets set by select countries.

EXHIBIT 6.1 **TRANSPORT DECARBONISATION AND NET-ZERO TARGETS FOR SELECT COUNTRIES**

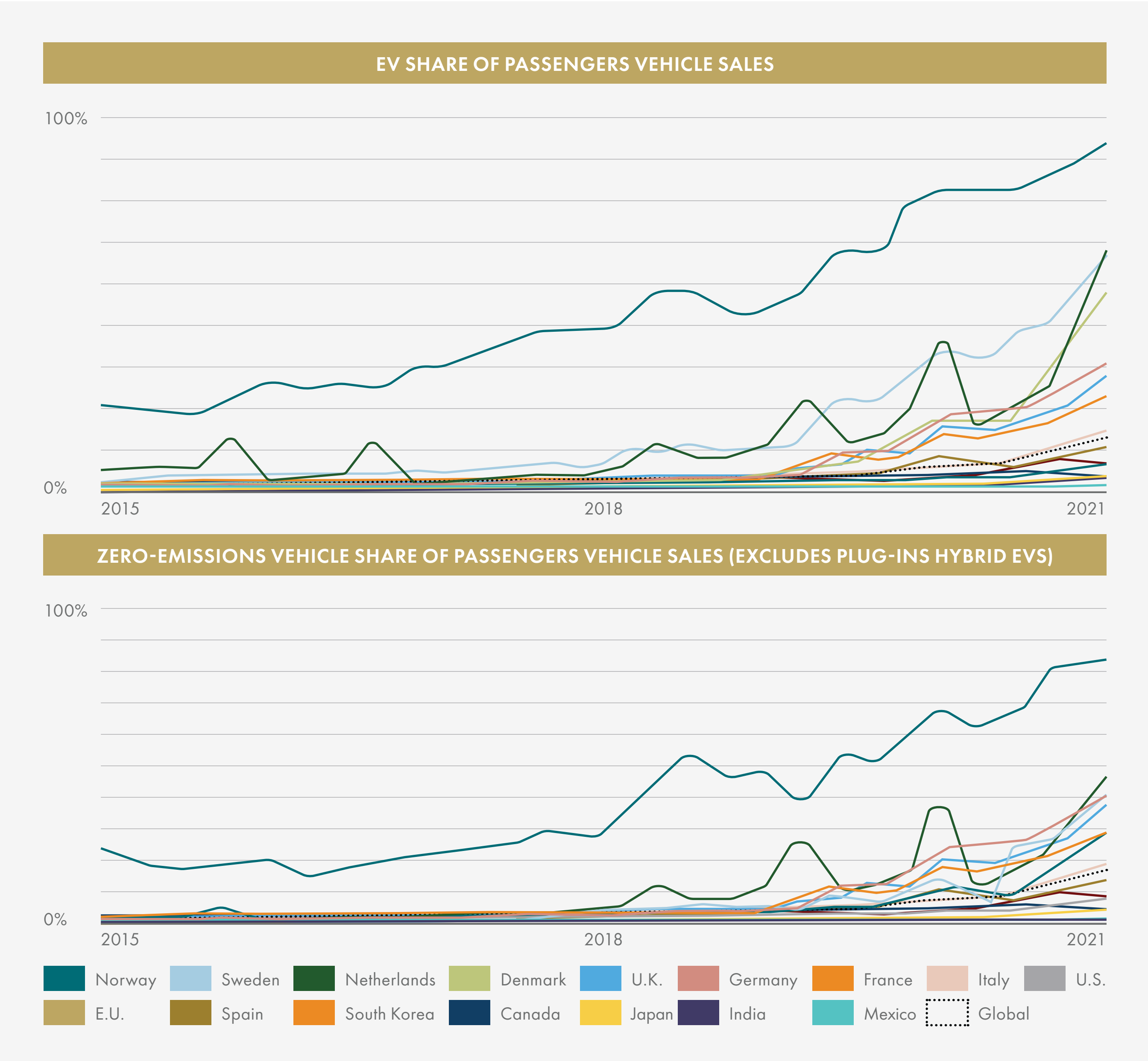


Source: International Energy Agency

One approach to mitigating these emissions is to shift to a cleaner transportation system, including the transition to electric vehicles (EVs). EVs often have lower life-cycle emissions (LCE) than comparable internal combustion engine (ICE) vehicles and, when powered with clean energy, can reduce GHG and local air pollutant emissions.[1] For example, the LCE of average medium-size EVs in 2021 was lower than those of comparable gasoline cars by 66%–69% in Europe, 60%–68% in the United States, 37%–45% in China, and 19%–34% in India.[2]

Already governments across the world are providing supportive policy ecosystems to drive adoption of EVs. From 2020 to 2022, the global share of EVs as a percentage of total sales increased from 4% to 14%.[3] Based on announced government targets, global EV sales are projected to reach 45 million by 2030, representing more than 35% of all vehicle sales.[4] China, Europe, and the United States are the largest EV markets today. More than 60% of global EV sales are in China. In Europe, Norway achieved 88% EV sales in 2022, the highest for any country in the world. In the EU and the United States, respectively, 21.5% and 8% of all sales in 2022 were electric.[5]

EXHIBIT 6.2 **ELECTRIFICATION TRENDS IN VARIOUS COUNTRIES**



Source: Bloomberg New Energy Finance

In India, the transport sector accounts for 14% of all Scope 1[6] carbon dioxide (CO_2) emissions for the country; of these emissions, nearly 90% are from road-based transport.[7] Therefore, the decarbonisation of road transport is a crucial pathway to achieve India's target to be net-zero by 2070.

Already, India has established ambitious electrification targets, including targets for EVs to constitute 30% of private car sales, 70% of commercial vehicle sales, and 80% of two- and three-wheeler sales by 2030. To accelerate the transition to EVs, the Government of India has provided incentives for EVs through policy mechanisms such as the Faster Adoption and Manufacturing of Electric and Hybrid Vehicles (FAME) scheme phases I and II. Additionally, 26 state governments have announced EV policies with state-specific targets, additional incentives, and other policy levers to create an enabling environment for EV adoption.[8] For example, Maharashtra has developed a suite of supporting policy mechanisms and set 2025 electrification targets, including for 10% of all new registrations to be electric and 25% of fleets, including public transport fleets, in Mumbai to be electric. As a result, 12.7% of all electric vehicle sales in the country for the 2022–23 fiscal year were from Maharashtra. Across India, 5.3% of all vehicle sales for the same year were electric.[9]

Charging and Swapping Infrastructure to Accelerate EV Adoption

Globally, the lack of charging and swapping infrastructure (hereinafter "charging infrastructure") is one of the biggest barriers to EV adoption.[10] Therefore, charging infrastructure must be deployed in anticipation of growth in EV sales. For example, in Norway, in 2011, there were already 1.3 light-duty vehicles per charger.[11]

EVs can charge with private charging at home or with publicly available charging. The distribution of charger type should reflect the local context. Built environments characterised by residences with dedicated parking space can place higher reliance on home chargers. Built environments with high-density housing (e.g., flats) and limited access to private chargers at parking spaces can rely more on public charging. Another key characteristic of the built environment is the mode of transport. As charging solutions vary by vehicle segment, charger deployment strategies should match the mobility patterns and vehicle segments in use. For example, in China, widespread deployment of fast charging solutions compensates for the lack of access to home chargers in densely populated cities.[12]

Furthermore, markets characterised by widespread availability of home charging will require public charging to cater to the needs of the population that does not have access to a designated parking space and to manage range concerns on longer trips.

BOX 6.1

LOS ANGELES

Deploying charging infrastructure matched to city needs

Status[13]

Los Angeles has the highest number of charging stations in the United States, stemming from several measures to accelerate adoption. Los Angeles has an estimated 29,000 chargers, of which 9,737 are public and 19,161 are shared private chargers (i.e., chargers installed at workplaces, multifamily residences, and similar settings that can be used by specific individuals).

Current housing pattern

19% of all residential units are flats (estimated at 55,000 flat units)[14]

EV penetration targets

Zero-emissions vehicle stock to constitute 25% by 2025, 80% by 2035, and 100% by 2050[15]

EV charger requirements for all new passenger vehicle sales to be EV by 2030[16]

An estimated 536,000 chargers, including 3,900 DC fast chargers, are required to meet 90% of charging needs under the proposed 2030 EV targets

Measures to accelerate charger deployment[17]

- Updating building codes to expand EV charging requirements
- Creating an expedited permitting and inspection process for charging stations
- Implementing consistent statewide standards for timely and cost-effective installation
- Expanding kerbside EV charger program to include the private sector
- Creating a training and certification program for 3,000 people to install charging infrastructure

Charging Infrastructure Deployment in India

The central government and multiple state governments in have taken several measures to encourage the deployment of charging infrastructure. The Government of India allocated ₹1,000 crores under the FAME II scheme for the deployment of charging infrastructure in cities and on highways. Under this program, in 2021 the central government sanctioned 2,877 charging stations in 68 cities across 25 states and union territories, as well as 1,576 charging stations along 9 expressways and 16 highways.[18] Additionally, the government has mandated that 20% of parking capacity in all new buildings be EV ready.[19] As of August 2023, with 9,113 public charging stations operational across India, the public charger–to-EV ratio stands at one-to-182.[20] Among states, Maharashtra has the highest number of public charging stations (2,494), followed by Delhi (1,627).[21] Together these two states have more than 45% of all public charging stations in the country.

EV adoption in India is concentrated in cities. The built environment in Indian cities is characterised by high density housing, such as multistory flat buildings. Therefore, access to home charging is limited, and public charging infrastructure is critical. Since two- and three-wheelers account for nearly 80% of all vehicle sales in India, the charger deployment strategy can prioritise installation of charging solutions for these vehicle segments. In other words, the charging strategy should match vehicle deployment forecasts.

Key Challenges to Charging Infrastructure Deployment in India

While several measures have been put in place to encourage the widespread deployment of accessible and affordable charging infrastructure, challenges to scaled deployment remain. They include:

1. **System-level challenges:** Challenges that pertain to the charging ecosystem as a whole.

    - **Standardisation and future-proofing:** EV charging technology and business models are rapidly evolving. Standardising technology can potentially stifle innovation. However, without standards, charging lacks interoperability, and future-proofing installations can be difficult. Though multiple charging standards have been published by the Government of India, the adoption of these standards in the two- and three-wheeler segments remains low.

    - **Limited scope for scaling public charging as a stand-alone business:** Consumers, especially those with access to designated parking space, prefer home charging. This, along with low EV penetration, means public chargers are often underutilised. In addition, the market is fragmented, with public charging as a service provided by such stakeholders as vehicle original equipment manufacturers, fleet operators, stand-alone charge point operators (CPO) and electricity distribution companies. The limited utilisation of public chargers and the fragmented market both create challenges for providers looking to achieve economies of scale, which can support the long-term viability of charging as a business.

2. **City-level challenges:** These challenges pertain to the built environment of the city. They are important, because most EV penetration in India is concentrated in cities. City-level challenges impact the charger deployment strategy of local governments and CPOs.

    - **Difficulty in obtaining sites:** Land is a scare resource in high-density cities, and identifying suitable parcels for public charging stations can be a challenge. For private charging, the lack of designated parking spaces with adequate load availability presents a challenge.

    - **Inadequate grid capacity and preparedness:** The grid often lacks capacity for large new loads from EVs. Infrastructure upgrades are costly and can deter the installation of charging stations. Limited regulatory measures, such as time of day tariffs and green energy open access, hinder efficient load management that would minimize infrastructure upgrade requirements.

    - **Lack of resource availability:** In India, urban local bodies (ULBs) have the mandate to ensure charging infrastructure deployment in cities. However, ULBs lack financial resources and personnel capacity, which limits their ability to draft enabling policies and provide financial incentives.

3. **Site-level challenges:** These challenges pertain to the specific characteristics of a site that are required for deploying charging infrastructure. They impact the technical and commercial feasibility of operating charging stations.

    - **Difficult to obtain technically feasible site:** It is difficult to obtain sites that have adequate space (including for upstream electrical infrastructure, signage and vehicle parking and movement) and available electrical load.

    - **Difficult to obtain commercially feasible sites:** Deploying charging infrastructure requires high up-front investment. This investment is further increased if costs pertaining to upstream electrical infrastructure are to be borne by the operator. Therefore, it is important that the site provides maximum utilisation of the chargers. Often this means obtaining sites in areas with high population and commercial density, where lease rates are high, thus further impacting the commercial feasibility of operating charging stations.

4. **Stakeholder-level challenges:** These challenges pertain to the impediments faced by different stakeholders vis-à-vis deployment and usage of charging stations.

    - **Consumers are not adequately informed:** Key challenges for the consumer include lack of information about installation, safe usage and maintenance of home charging solutions, and discoverability, accessibility, affordability, and interoperability of public charging stations. The lack of process clarity for utilising incentives (subsidies and EV tariffs) is also an impediment for the consumer.

    - **Developers lack regulatory clarity:** A key challenge for developers, especially in existing buildings, is providing a private charging facility to all residents, which requires significant investment in both electrical and civil infrastructure. Developers lack clarity on regulatory compliance and the approvals required for the safe installation of charging infrastructure in buildings. For instance, if a transformer is installed for EV charging in an approved building, are developers required to retake approvals from ULBs? The lack of parking and charger usage guidelines is also a key challenge, especially in areas where designated parking for residents is not available.

    - **Charge point operators lack business model flexibility and financial subsidies:** The key challenges for charge point operators are the difficulty in obtaining sites and the lack of freedom in determining charger combinations for public charging stations built with government support. The absence of adequate financial incentives, coupled with high costs and low initial returns for operating charging stations, impacts business viability. Another challenge is the need for future-proofing infrastructure to account for changes in technology and policy.

PALAVA TOWNSHIP AS A TEST BED

There is an urgent need to develop proof points for charging infrastructure deployment, to capture lessons learned that provide solutions to the aforementioned challenges and others, and to drive scale.

Lodha has resolved to be net-zero by 2035. To achieve this goal, it has initiated the Lodha Net Zero Urban Accelerator program in partnership with RMI India Foundation. Clean mobility is one of the key focus areas of the Accelerator, and Lodha's flagship property, Palava, is an ideal test bed to develop these proof points. Palava is representative of the rapid urbanisation trend in India, which is accompanied by an increasing share of flats as dwelling units.[22] The township is characterised by affordable and high-density housing, which is a good proxy for the built environment in Indian cities.

About Palava and its Vision for Clean Mobility

Palava is India's first integrated greenfield smart city, located in Maharashtra at the junction of Thane, Navi Mumbai and Kalyan. Covering 4,500 acres and home to more than 33,000 families, Palava was designed with a vision of providing a sustainable solution to India's urbanisation challenges. Supporting Lodha's target to be net zero by 2035, Palava is committed to enabling a clean mobility transition for residents. This transition depends on an accelerated shift to electric mobility, including buses used for public transport, two- and four-wheelers for commercial purposes such as last-mile delivery, and private two- and four-wheelers for personal mobility. Following is the vision statement for vehicle electrification in Palava:

> To enable a phased, timebound, sustainable and inclusive transition of all two- and four-wheelers, including legacy internal combustion engine vehicles, to electric in the Palava township by 2045. Palava will be a replicable model for townships in India and across the world.

The deployment of EV charging infrastructure will be the cornerstone that enables the transition to EVs. To ensure an inclusive and sustainable transition, it is imperative that the township finds a balance between deploying widespread charging infrastructure, ensuring accessible and affordable charging and optimising energy consumption.

CHARGING AND SWAPPING INFRASTRUCTURE DEPLOYMENT ACTION PLAN

Lodha is developing an action plan that provides a roadmap for deploying an EV charging network in the Palava township. The roadmap does the following:

- **Provides a detailed assessment of charging infrastructure requirements** based on vehicle electrification projections and Palava-specific use cases
- **Presents a deployment strategy** by delineating the guiding principles and models of deployment and tendering best practices
- **Ensures technology and infrastructure investments are future-proofed** to enable a "right the first time" transition
- **Maps roles and responsibilities** to coordinate decision-making and promote accountability
- **Establishes a monitoring and evaluation (M&E) process** to facilitate deployment modifications and document learnings to inform scaling

The action plan is arranged in three sequential parts to support staged and timely decision-making. Together, the three parts detail the full plan for the deployment of charging infrastructure in the Palava township.

Covered within the scope of this chapter are:

- The **guiding principles** to anchor the deployment of EV charging and swapping infrastructure in the Palava township
- **Annual vehicle electrification targets** for priority vehicle segments and use cases
- **Annual charging infrastructure deployment targets** for various charging scenarios
- **Additional load projections** for each charging deployment scenario

Subsequent sections (Part II & III) will be released in future publications.

Part II will consist of: Deployment models, selecting standards/solutions and tendering best practices
It will dive deep into the steps to be taken to achieve the targets outlined in Part I. It will delineate the process to identify vendors, select appropriate charging standards and solutions, recommend models of deployment, assign timelines for deployment and undertake responsibility mapping for each stakeholder.

Part III will consist of: Lessons learned, course corrections and revised targets
The third part will capture the learnings from implementation to guide scaling in Palava and beyond. It will also recommend modifications to the implementation strategy, if needed.

VEHICLE ELECTRIFICATION TARGETS AND CHARGING INFRASTRUCTURE REQUIREMENTS

RMI India Foundation and Lodha developed a quantitative model to assess Palava's vehicle electrification targets for the priority segments (private two- and four-wheelers and commercial four-wheelers), as well as the associated charger deployment targets and load forecasts.

The model first assesses vehicle electrification targets for an aggressive scenario and a business-as-usual (BAU) scenario.

- Aggressive scenario: This scenario models a high EV adoption rate based on the electrification trends in Mumbai and in progressive countries such as Norway. The inputs are contextualised to Palava to develop an ambitious but realistic scenario.

- BAU scenario: This scenario is a baseline for vehicle electrification based on the current electrification trends in Mumbai and the national targets set by the Government of India.[23]

The scenarios consider the number of new EVs purchased by Palava residents and the replacement of existing ICE vehicles with EVs.

The model also incorporates Palava-specific parameters including projected occupancy, vehicle ownership trends, and resident profiles.

The requirements for charging infrastructure consider Palava's high density, availability and type of parking (e.g., multilevel car parks, kerbside, and other) and general mobility patterns. Based on these factors, a high reliance on public chargers is necessary to meet the needs of residents and commercial operators. Furthermore, the charger technology deployed is based on several assumptions for use case and technology availability, including the predicted availability and technical specifications. These assumptions are described in detail in the Appendix.

EXHIBIT 6.3 **CHARGING SOLUTIONS FOR PRIORITY VEHICLE SEGMENTS**

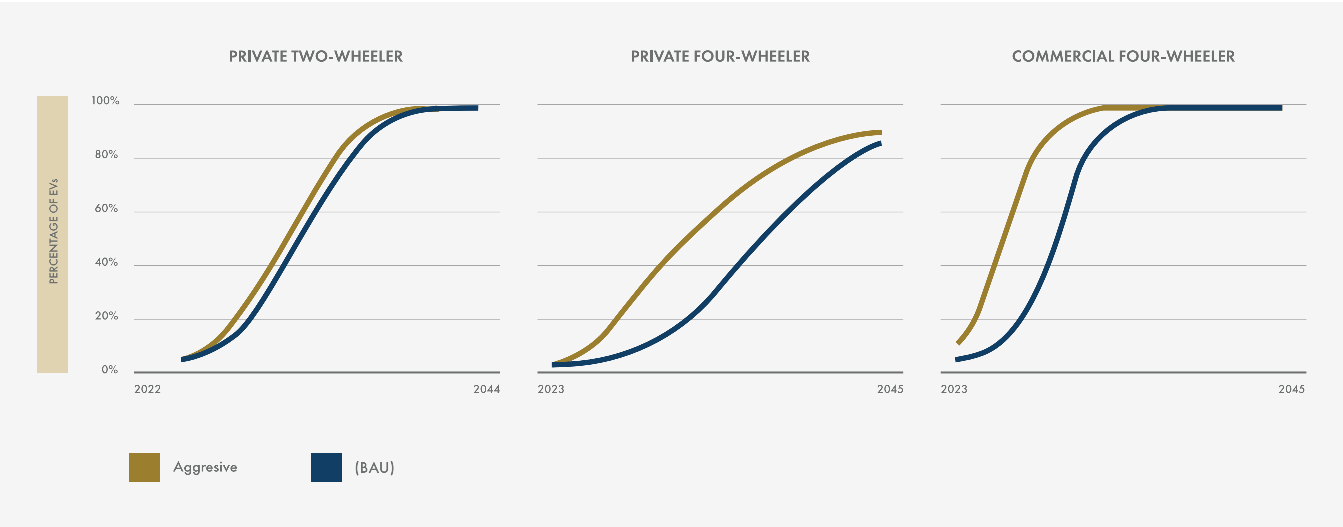
Vehicle Segment	Common Battery Capacity (kilowatt-hour)	Alternating Current (AC) Charger Type	Direct Current (DC) Charger Type	Time to Full Charge
Two-wheeler	1.2–4	LEV AC, 3.3 kilowatt (kW) Battery swapping (for commercial use cases)	LEV DC, 5 kW	AC charging: 4 to 10 hours DC charging: 40 minutes to 2 hours
Four-wheeler	17–70	LEV AC, 3.3 kW Type 2 AC, 7.2 kW	DC 001, 15 kW CCS, 30 kW CCS, 50 kW	AC charging: 6 to 12 hours DC charging: 1 to 1.5 hours

Source: RMI India Foundation Analysis

Vehicle Electrification Targets

Exhibit 6.4 shows the electrification targets for BAU and the aggressive scenario. It is forecasted that all new vehicles bought by Palava residents will be electric by as early as 2035 in the aggressive scenario, whereas the same target is achieved in 2045 for BAU. For total vehicle stock, by 2035, an estimated 86% of vehicles are electric in the aggressive scenario. Commercial vehicles see the highest rates of EV adoption, followed by private two-wheelers and four-wheelers.

EXHIBIT 6.4 **VEHICLE ELECTRIFICATION TARGETS – AGGRESSIVE AND BAU SCENARIOS**



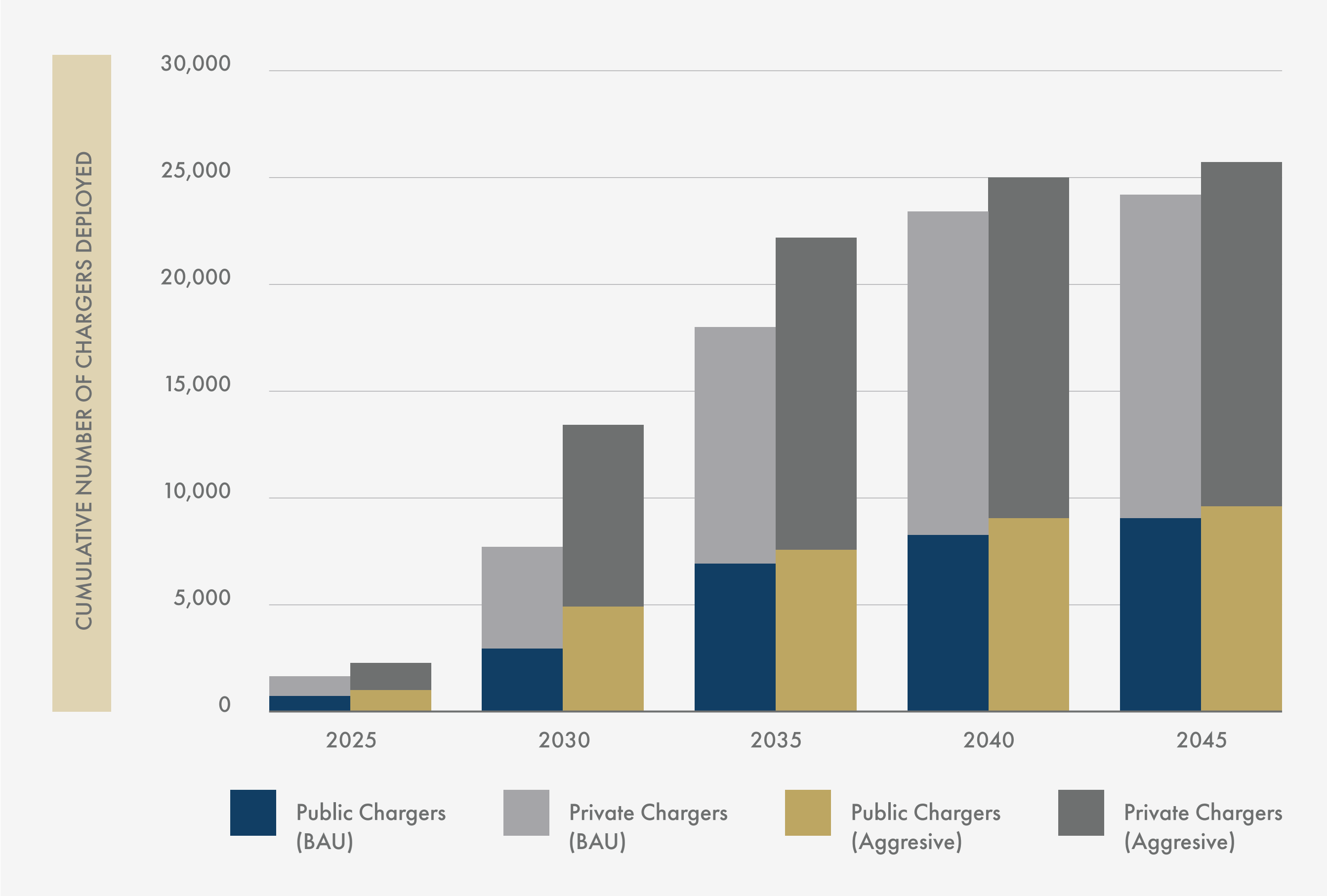
Source: RMI India Foundation Analysis

Charger Deployment Targets

Ultimately, the total charger count deployed by 2045 is similar for both scenarios. However, in the aggressive scenario, chargers are deployed earlier to match the rapid adoption of EVs in the early years of the transition.

In the aggressive electrification scenario, 15,929 private chargers and 9,744 public chargers will be deployed by 2045. Similarly, in the BAU vehicle electrification scenario, 15,426 private chargers and 9,297 public chargers will be deployed by 2045.

EXHIBIT 6.5 **CUMULATIVE CHARGERS DEPLOYED IN BAU AND AGGRESSIVE SCENARIOS, 2025–2045**



Source: RMI India Foundation Analysis

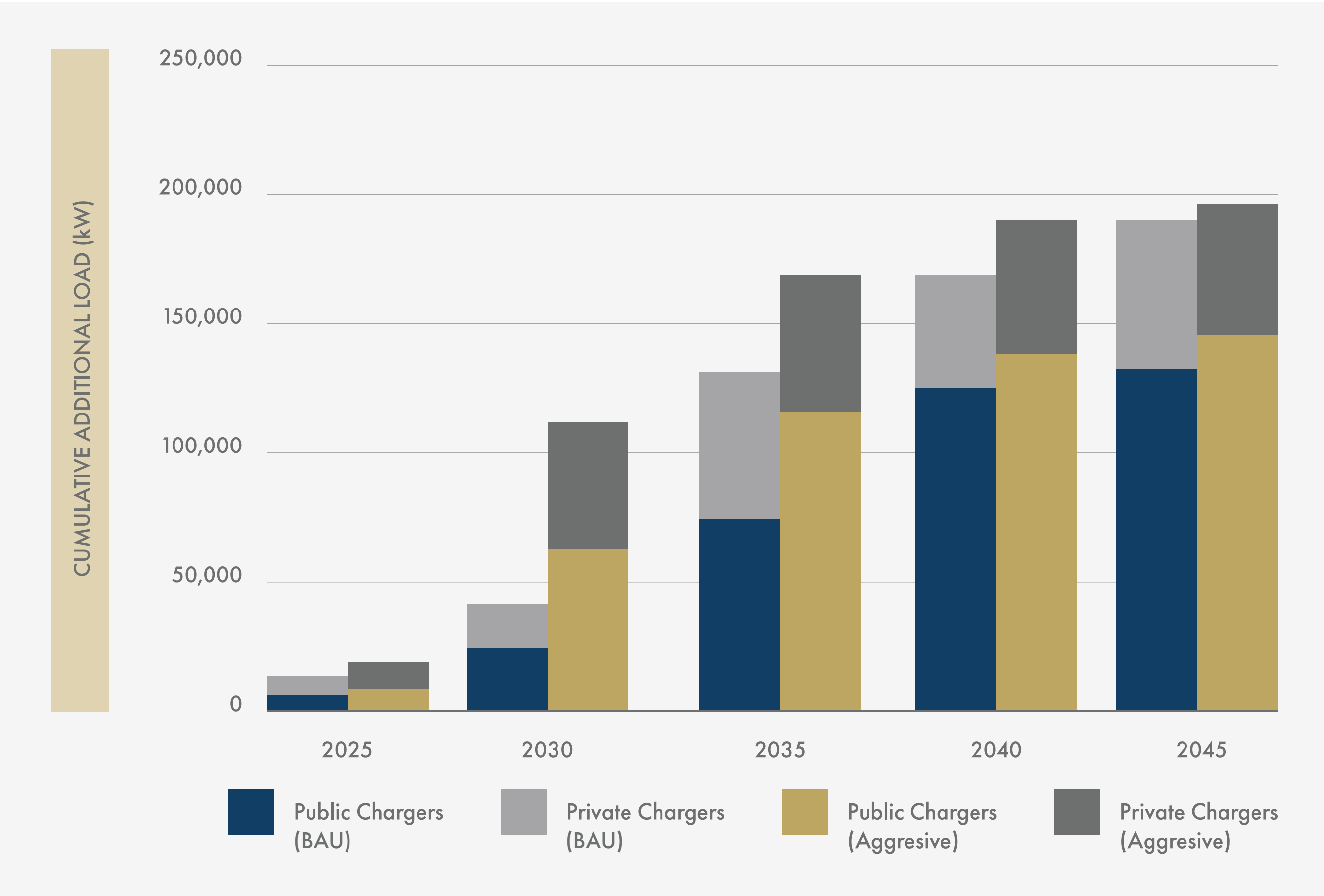
Load Requirement Projections

The forecasted new load peaks at an estimated 195,000 kW in the aggressive scenario. The cumulative new load required to meet the 2045 charger deployment targets in the aggressive scenario is an estimated 195,000 kW. The estimate assumes simultaneous use of chargers to assess sanctioned load requirements. However, energy infrastructure will need to be sized on a continuous basis as charging behaviour for Palava is better understood and in line with the appropriate regulatory guidelines. Nearly three-fourths of this load comes from public charging; although more private chargers are deployed than public chargers, it is expected that public chargers will have higher outputs and contribute disproportionately to new load.

Looking forward, the geographic distribution of chargers will be determined, and load assessments can be performed at the distribution transformer level to assess if the existing infrastructure can handle the new load or if enhancements are required.

Exhibit 6.6 shows the cumulative additional load required every five years under both electrification scenarios for public and private charging.

EXHIBIT 6.6 **CUMULATIVE ADDITIONAL LOAD REQUIRED, 2025–2045**



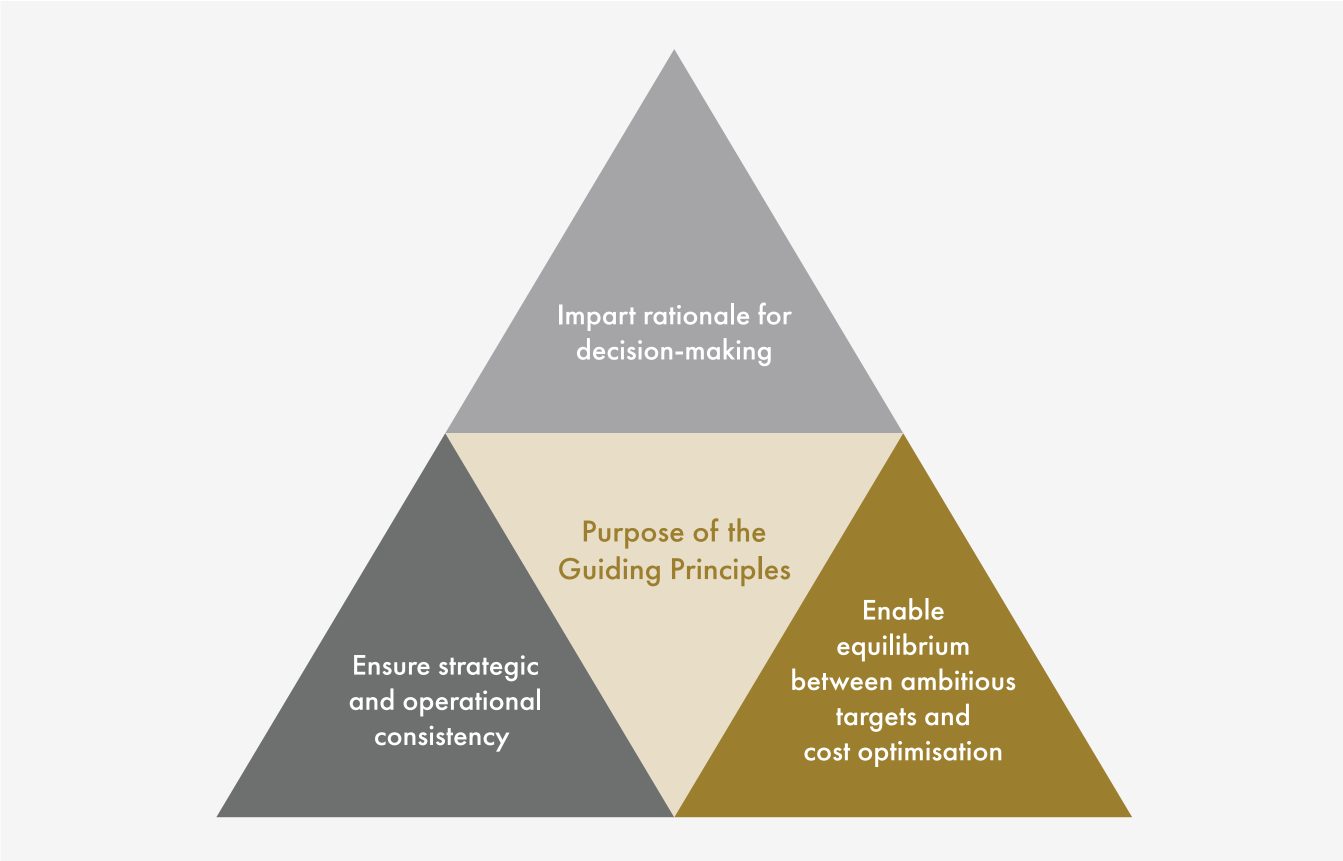
Source: RMI India Foundation Analysis

GUIDING PRINCIPLES FOR CHARGING INFRASTRUCTURE DEPLOYMENT

The deployment of EV charging solutions in Palava township will follow a set of guiding principles. The purpose of the guiding principles is to:

- Impart rationale to short-, medium- and long-term decisions
- Enable a balance between Palava's ambitious electrification targets and optimising the investment required to achieve these targets
- Provide strategic and operational consistency to the deployment process

EXHIBIT 6.7 **PURPOSE OF THE GUIDING PRINCIPLES**



The guiding principles are:

1 **Prioritise electrification of two- and four-wheelers**
The vehicle ownership and mobility patterns of the township require prioritising the electrification of private and commercial two- and four-wheelers.

2 **Apply evidence-informed approach**
Electrification targets will be based on leading examples from India and beyond that are contextualised to Palava. Multiple scenarios will model a range of future conditions to allow for flexibility in the target setting.

3 **Provide technology- and solution-agnostic approach**
The strategy will consider all charging technologies, and technologies will be chosen based on use-case needs.

4

Future-proof infrastructure investments

Because the EV charging sector is evolving rapidly, the deployment strategy will take technology and business developments into consideration to future-proof early investments in infrastructure.

5

Ensure accessibility for consumers

Equitable geographical distribution of chargers within the township will be mandated to ensure charging infrastructure is accessible to residents.

6

Enable affordability for consumers

A consumer-centric approach will be taken that encourages affordable charging. Innovative business models that include defraying costs and streamlining processes will be developed to minimise the costs for consumers.

7

Prioritise shared charging

The deployment of shared charging infrastructure, including shared chargers in multilevel car parks and public chargers, will be prioritised. Deploying shared charging infrastructure can help reduce costs by limiting the number of chargers needed, while still managing for range concern and providing residents with convenient access to chargers. Deploying solutions to provide managed charging can shift load to off-peak hours and minimise costs.

8

Integrate renewable energy

The sourcing of RE for charging and the deployment of RE-powered charging stations will be encouraged.

9

Follow a phased and least-cost approach

A phased deployment action plan will right-size the charging network based on the needs of residents, thereby encouraging EV adoption and providing an adequate charging network. Phased deployment can also accommodate advancements in technology and business models.

10

Ensure continuous M&E

To assess progress and modify deployment targets and strategy, an M&E framework and process will be used. The assessment framework will consider the status of implementation, the feasibility of targets, the existing and future EV profile of the township and the past impact of EV chargers on the EV transition.

11

Create awareness among residents

EV awareness campaigns about the benefits of EVs and measures taken to facilitate adoption of EVs will be conducted by engaging with residents throughout the planning and execution process.

WAY FORWARD

To initiate charging infrastructure deployment and spur the adoption of EVs at Palava, Lodha is developing a charging infrastructure deployment action plan. Lodha will convene stakeholders to gather inputs that inform the deployment. A **designated working group** will be formed with representatives from Lodha, Palava residents, and external experts. Building on the inputs from the convening and on the charging infrastructure deployment guiding principles, the working group will:

- **Site charger locations** with a siting framework that considers equitable access and the technical and economic feasibility of operations
- **Select the appropriate charger technologies** for deployment in consultation with vendors

- **Develop a phased deployment strategy**, including a timeline for implementation, recommendations for selecting vendors and negotiating vendor scope, expectations for the upkeep of charging stations, and an M&E framework

- **Map roles and responsibilities** for each phase of the transition to ensure seamless decision-making and deployment

Setting vehicle electrification and charger deployment targets for the Palava township will kick-start the planning required for a supportive network that enables the accelerated electrification of vehicles. The ambitious and contextualised deployment targets can establish Palava as a leader in vehicle electrification.

As the next step, Lodha will develop a timebound implementation strategy, using the inputs obtained from the stakeholder convening and guiding principles as an anchor to further Palava's electrification activities.

As part of the Accelerator, a key aim of deploying charging infrastructure in Palava is to develop proof points and capture lessons learned through deployment to help the ecosystem understand and overcome barriers to charging infrastructure deployment.

Several questions this process seeks to answer are:

- What measures must be taken to ensure regulatory compliance when installing charging stations?

- What are the commercial implications of adhering to regulatory requirements pertaining to achieving EV readiness for parking spaces in buildings?

- What is the best method to optimise costs through a balance of public and home chargers? Should developers prefer one over the other?

To facilitate learning within the ecosystem, Lodha will report on the progress, capture and disseminate critical knowledge with all stakeholders, and facilitate the development of solutions to promote scaling of charging infrastructure deployment in Palava and beyond.

APPENDIX

Model Inputs and Assumptions for Charger Deployment

In modelling charger deployments, the following assumptions were made with respect to applicable technology and application per use case:

- To assess the ratio of public and private charging infrastructure requirements, several assumptions were made to account for vehicle use-case, and the mobility patterns and available parking infrastructure at Palava. These assumptions include:
    - Private two-wheelers: 80% and 20% of charging needs are met by public and private charging, respectively
    - Private four-wheelers: 70% and 30% of charging needs are met by public and private charging, respectively
    - Commercial four-wheelers: 80% of charging needs are met by public chargers; all else is met by captive chargers managed by the commercial entity
- The power output for two-wheeler AC chargers is assumed to be 3.3 kW. While the latest guidelines of the Government of India define Level 1 (both AC and DC) for LEVs up to 7 kW, chargers for two-wheelers are expected to have a power output of 3.3 kW because the mobility needs and price sensitivity of Indian consumers do not support a drastic increase in battery size.
- Interoperable LEV DC chargers are projected to be ready for commercial deployment by 2025 and will have a power output of 5 kW. Propriety LEV DC chargers are available in the market. However, as they cater to specific manufacturers of two-wheelers, they are not expected to be widely deployed in the township.
- It is assumed that 80% of all public chargers for private four-wheelers will be CCS 50 kW DC chargers. The power output of the remaining chargers will vary based on the assumed increase in onboard charger capacity in the future.
- It is expected that 80% of all electric commercial four-wheelers will require public or shared chargers to support long-distance daily operation, and that 100% of these chargers will be DC chargers. While 100% of these vehicles will use DC 001 (15 kW) chargers in the initial years, the percentage share of chargers that are DC 001 (15 kW) or CCS (50 kW) will change over time.

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19. Per India's building by-laws (2016), charging infrastructure shall be provided on 20% of all vehicle-holding capacity/parking capacity of the premises. The building premises must have capacity for the additional power load with a safety factor of 1.25. EV-ready parking spots shall be equipped with all conduit, wiring, and panel capacity and require only the installation of the EV charger. EV-ready buildings include the installation of dedicated branch circuit(s), circuit breakers, and other electrical components.

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23. By 2030, 80% of the two-wheelers, 70% of the commercial vehicles, and 30% of the private four-wheelers will be electric.

CHAPTER 7

RE Procurement Pathways for Consumers in India

LIST OF ABBREVIATIONS USED IN CHAPTER 7

ABBREVIATION	DEFINITION
ALMM	Approved List of Models And Manufacturers
APTEL	Appellate Tribunal for Electricity
AS	Additional Surcharge
BCD	Basic Custom Duty
BESS	Battery Energy Storage System
BIS	Bureau of Indian Standards
CAGR	Compound Annual Growth Rate
CSS	Cross Subsidy Surcharge
C&I	Commercial and Industrial
Discom	Distribution Company
DT	Distribution Transformer
GEOA	Green Energy Open Access
GoI	Government of India
GW	Gigawatt
HUD	United States Department of Housing and Urban Development
ISTS	Inter State Transmission System
kWh	Kilowatt-hour
LED	Light-emitting Diode
MoP	Ministry of Power
MSMEs	Micro, Small, And Medium Enterprises
OA	Open Access
OTC	Over the Counter
PPAs	Power Purchase Agreements
PLI	Production-linked incentives
PX	Power Exchanges
P2P	Peer-to-peer
RE	Renewable Energy
RECs	Renewable Energy Certificate
RTS	Rooftop Solar
SGD	Safeguard Duty
VPPA	Virtual Power Purchase Agreement
VNM	Virtual Net Metering

INTRODUCTION

The Government of India (GoI) endeavours to meet 50% of the country's electricity demand with non-fossil-fuel electricity by 2030, which necessitates over 50GW of RE deployment every year. This is a massive challenge as India has awarded a maximum of only about 30GW in annual auctions of RE capacity thus far. Hence, consumer uptake of RE will play a key role for India to meet its 2030 targets.

The C&I sector, including real estate developers and commercial offices, accounts for almost 36% of India's electricity consumption, while domestic consumption constitutes another 30%. The plummeting costs of RE over the last decade and financial incentives (for domestic consumers) provide consumers across segments a lucrative opportunity to switch to RE and reduce their electricity costs while ensuring the country moves one step closer towards its 2030 RE goals.

Although there exists clear value in rapidly scaling the consumer adoption of RE, C&I consumers currently procure less than 10% of their electricity via RE and the country as a whole has met only about 26% of the 40GW RTS target thus far. To increase RE adoption in the country, consumers need clarity on the existing and emerging RE procurement pathways that can be tapped based on their requirements, associated costs, benefits and limitations. This can be a challenge for consumers as the policy and regulatory environment at the central and state levels is constantly evolving and can influence the feasibility of RE procurement pathways substantially.

This section lays out the large array of long- and short-term RE procurement pathways available to domestic C&I consumers in India. It highlights key considerations across the policy, regulatory, financing and technical spectrum of the RE procurement landscape, which can either spur or inhibit future growth in consumer adoption. It also shines a light on innovative models trending across the globe and how they can help unlock additional pathways for consumers to seamlessly adopt RE. Finally, this section provides a clear framework for consumers to design their individual RE procurement pathway based on their specific needs. It draws from best practices and lessons from global interventions in the RE procurement space.

Lodha has committed to meet 100% of its electricity demand with RE by 2025. The pathways adopted should lead to electricity cost savings for the group, which has deployed solar capacity of about 2MW with an additional 1.3MW expected in 2023.

Since the launch of the Net Zero Accelerator last year, Lodha has engaged with multiple stakeholders, including some of the country's biggest RE developers, to identify on-site and off-site RE deployment pathways. The lessons learned from these discussions are captured in the following sections.

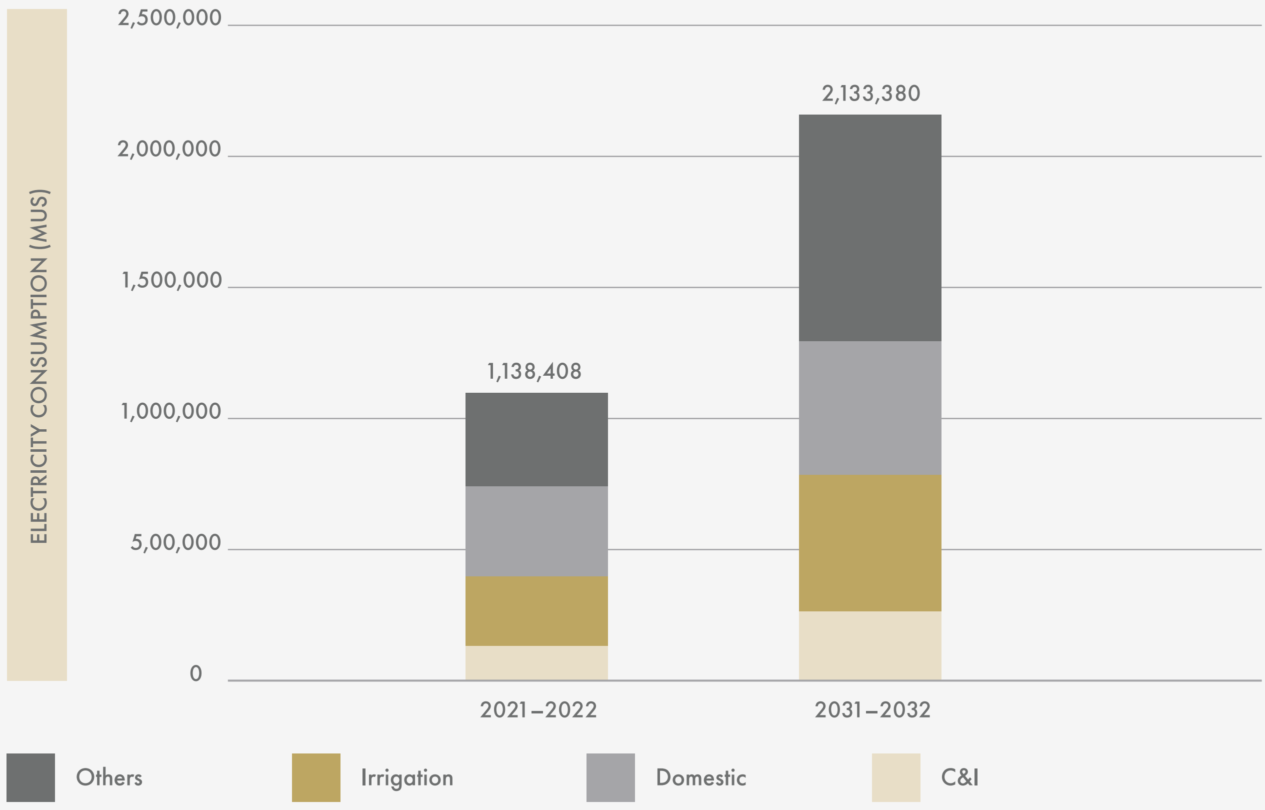
EVOLUTION OF RE PROCUREMENT IN INDIA

Role of C&I in India's electricity sector

India's GDP growth is expected to average over 6% annually till 2030 and projected to become the world's third largest economy. The crucial role that commercial, industrial and infrastructural development activities will play in the country's growth story is evident from the extensive budgetary support announced for different sectors in recent years in the form of production-linked incentives (PLI). For instance, in 2021, PLI schemes of around ₹2 lakh crore were announced for 14 different sectors to encourage large-scale domestic manufacturing. A key ingredient needed to support existing and new manufacturing capacity in the country is access to critical resources such as water and electricity at viable rates to support India's competitiveness against global peers.

Increasing commercial and industrial activity in India will fuel electricity demand which is projected to rise by over 80% by the end of this decade. C&I consumers currently account for 36% of the total electricity consumed in the country and will constitute nearly 40% in a decade, followed by domestic electricity demand making up about 30% of the country's total demand (Exhibit 7.1).

EXHIBIT 7.1 **COMPARISON OF ELECTRICITY CONSUMPTION PROFILES BETWEEN 2021–22 AND 2031–32**



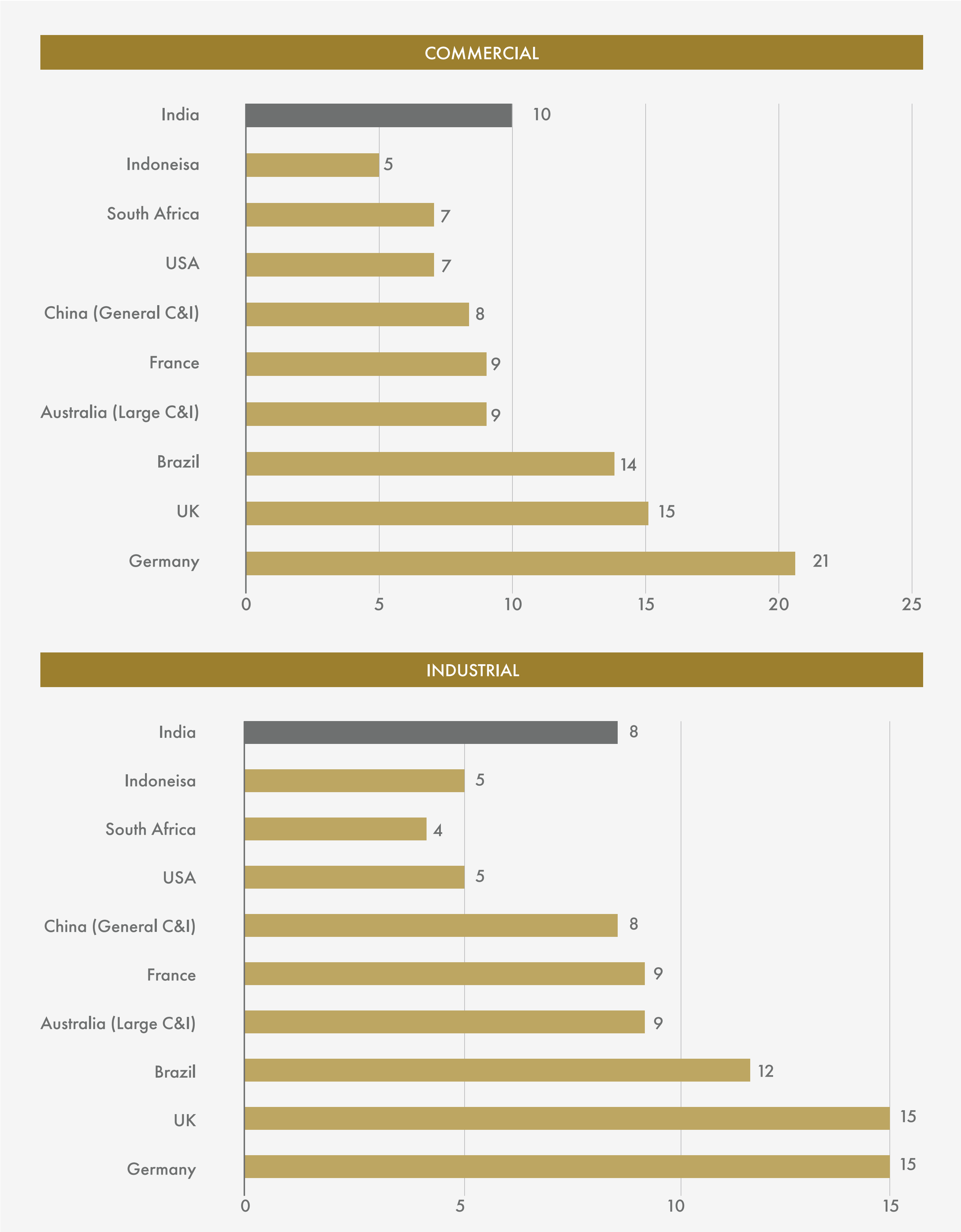
Note: Others includes public lighting, public water works, railway traction, bulk supply and open access consumption not accounted for by Discoms

Source: CEA, 20th Electric Power Survey

GLOBAL COMPARISON OF ELECTRICITY PRICES FOR C&I CONSUMERS

C&I consumers pay the steepest electricity tariff among all consumer classes in India. These tariffs are some of the highest among many global peers, as highlighted in Exhibit 2. C&I consumers in India typically pay ₹8–10 per unit of electricity. These prices are significantly higher than those in the United States, China, South Africa and Indonesia and comparable with those in France and Australia. The high electricity tariffs in India are a function of cross-subsidies, wherein the high tariff paid by C&I covers the subsidised tariff for the residential and agricultural sectors. Elevated electricity tariff significantly affects the local and global competitiveness of domestic micro, small, and medium enterprises (MSMEs), as electricity costs can make up as much as 50% of their total expenses in some cases.

EXHIBIT 7.2 **COMPARISON OF C&I TARIFFS GLOBALLY (₹/kWh)**

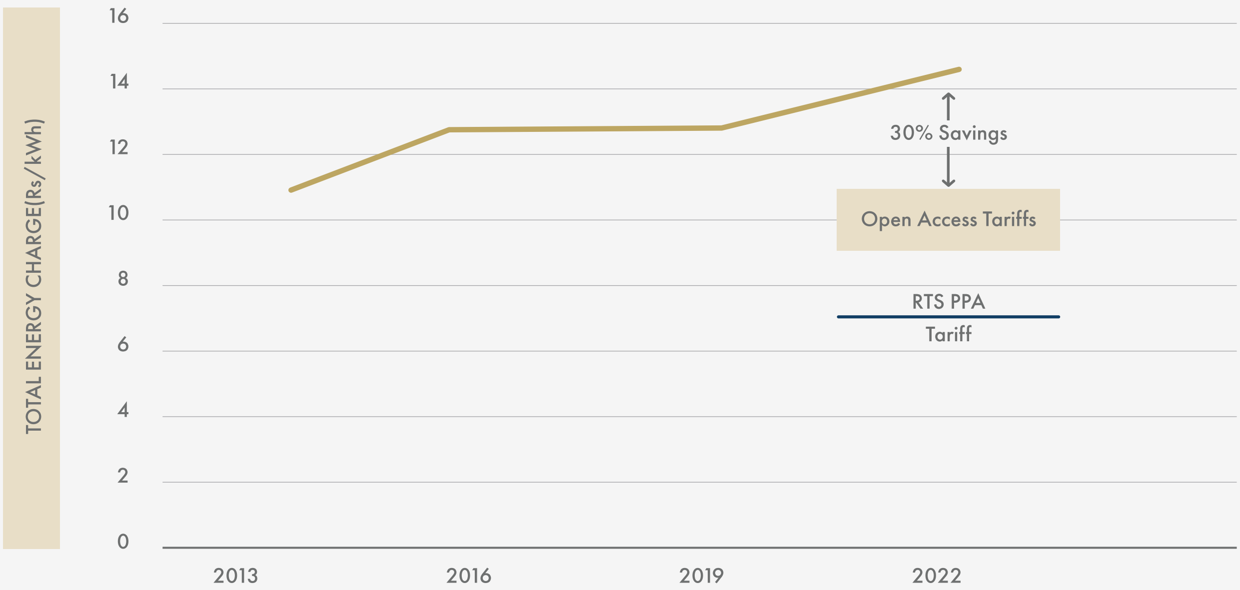


Source: CSEP, 2022

Role of RE in optimising electricity costs

India's solar and wind installed capacity has increased from 18GW in 2011 to around 114GW in 2023, primarily driven by the growing cost competitiveness of utility-scale RE generators compared with conventional generators. Discoms across India continue to add RE generation in their portfolios at record-low tariff to optimise their power procurement costs. Despite this, electricity tariff for consumers have continued to rise consistently, driving them towards adopting low-cost renewable generation pathways to minimise existing and future electricity costs.

EXHIBIT 7.3 **COMMERCIAL TARIFFS IN MAHARASHTRA**



Note: The lower range of the open access tariff represents tariff for open access captive consumption, and the higher range represents tariff for OA third-party procurement

Source: CEA, Reports on Tariffs and Duties of Electricity Supply, Bridge to India 2021

In Maharashtra, electricity tariff for commercial consumers posted a consistent CAGR of 5% from about ₹10 per unit to over ₹15 per unit in the last decade, as seen in Exhibit 7.3. At this rate, tariff could cross ₹20 per unit by 2030. The rise in tariff and plummeting costs of RE make it extremely lucrative for commercial consumers in Maharashtra who can achieve more than 30% savings on their tariff by adopting open access (OA) or RTS.

The landed costs for off-site RE-based electricity procurement for C&I consumers across India can range from around ₹4 per unit for OA solar in captive mode to ₹10 per unit for

OA wind via third-party procurement. RTS remains the cheapest option available at less than ₹4 per unit. Based on this, C&I customers can lower their electricity costs by 60–75% when procuring RE power via OA solar and RTS. The savings grow over the lifetime of the RE asset as the electricity rates under OA are usually locked in through the lifetime of the RE asset. Hence, the consumer is shielded from rising electricity tariff, thus resulting in increased savings (Exhibit 7.3).

Assessment of residential RE procurement in India

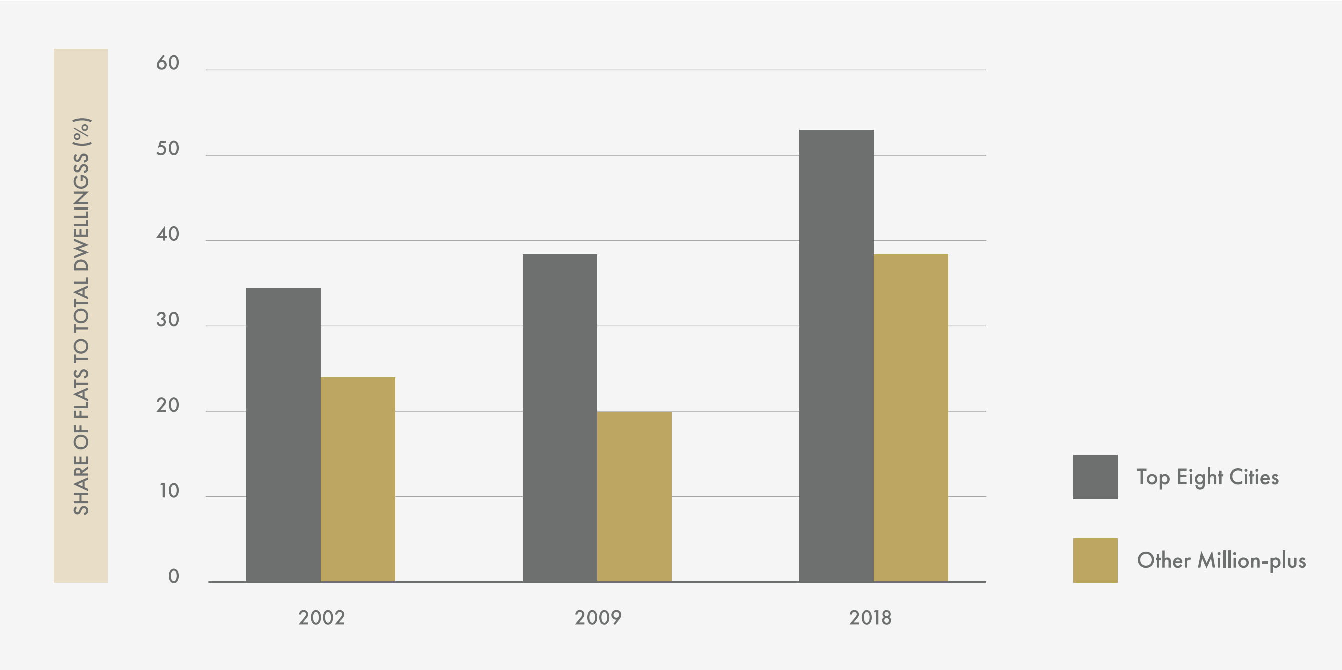
RTS makes up nearly 17% of the solar installed capacity across India and is primarily driven by C&I consumers in the country. The cumulative RTS deployment among residential consumers stands at just 2.6GW and accounts for only 22% of the RTS deployment in the country. This deployment is highly concentrated in a few states, with over 60% of the residential RTS capacity deployed in Gujarat.

The slow growth in residential RTS adoption can be attributed to multiple key factors, including availability of rooftop space, awareness and accessibility of incentives and lack of innovative financing mechanisms.

The challenge is compounded by an emerging trend among consumers residing in flats and multi-dwelling buildings, as reflected in the increasing share of flats across the majority of the large cities in India (Exhibit 7.4). Across India's major cities, the penetration of flats as a percentage of total dwellings has grown from roughly 30% to over 50% in the last two decades. Additionally, over 30% of the residents, especially in major cities, live in rented accommodation.

These consumers do not have access to exclusive rooftops, and the existing policy and regulatory environment offers no RE procurement models for such consumers despite the availability of lucrative economic incentives and significant savings for residential consumers.

EXHIBIT 7.4 **CHANGING HOME OWNERSHIP TRENDS IN INDIA**



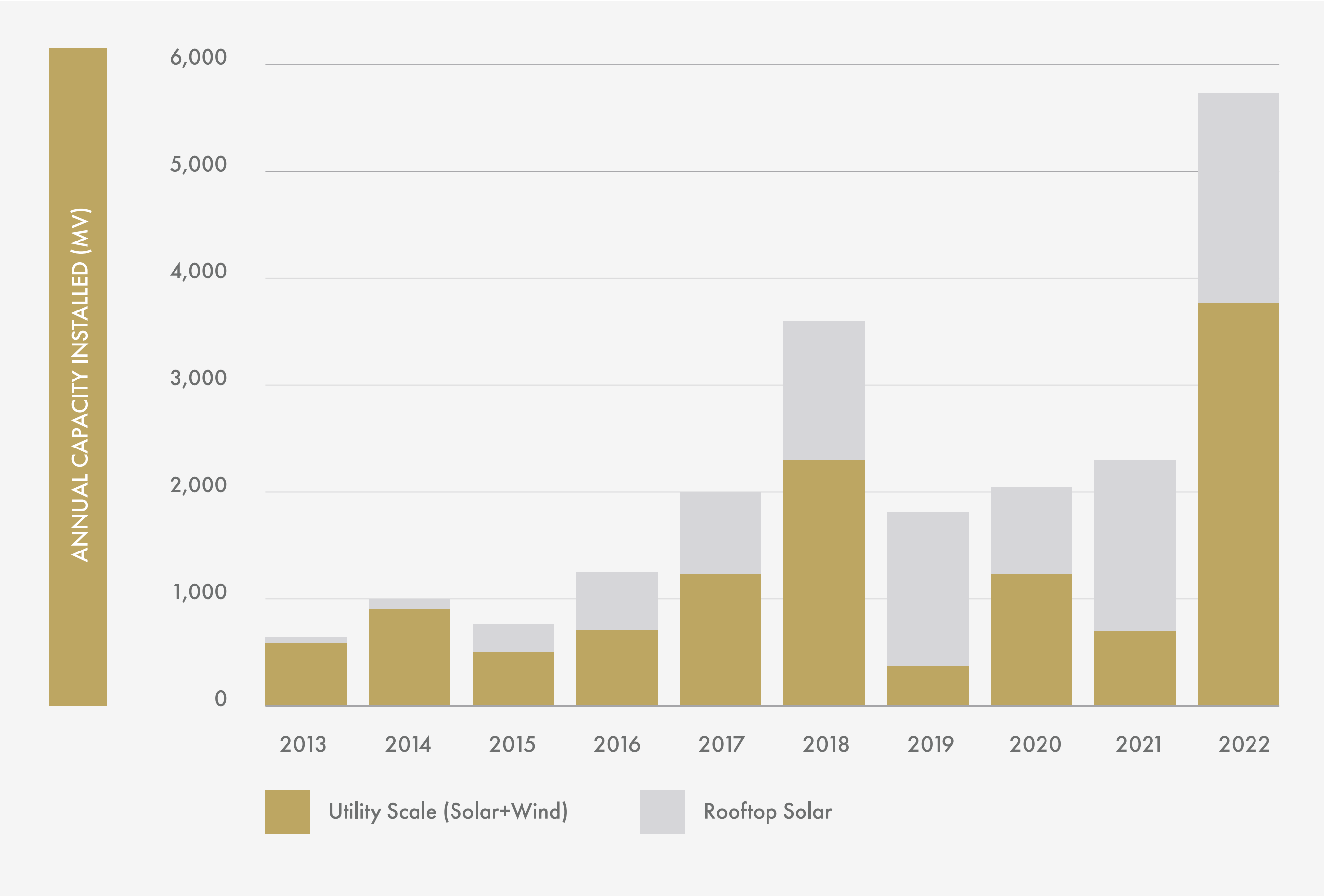
Source: India Housing Report, Centre for Policy Research

RE PROCUREMENT PATHWAYS IN INDIA

Evolution of RE procurement by C&I consumers

As highlighted in the previous section, the high cost of electricity for C&I consumers and low-cost RE in India are leading consumers in the C&I sector to increasingly consider RE procurement for their electricity needs (Exhibit 7.5). In the last decade, C&I renewable capacity addition in India recorded a CAGR of 23%, with capacity addition in 2022 being over three times that deployed in 2019. India was second only to the United States in terms of a growth market for corporate renewable PPAs in 2019.

EXHIBIT 7.5 **ANNUAL C&I RE INSTALLED CAPACITY (MW)**



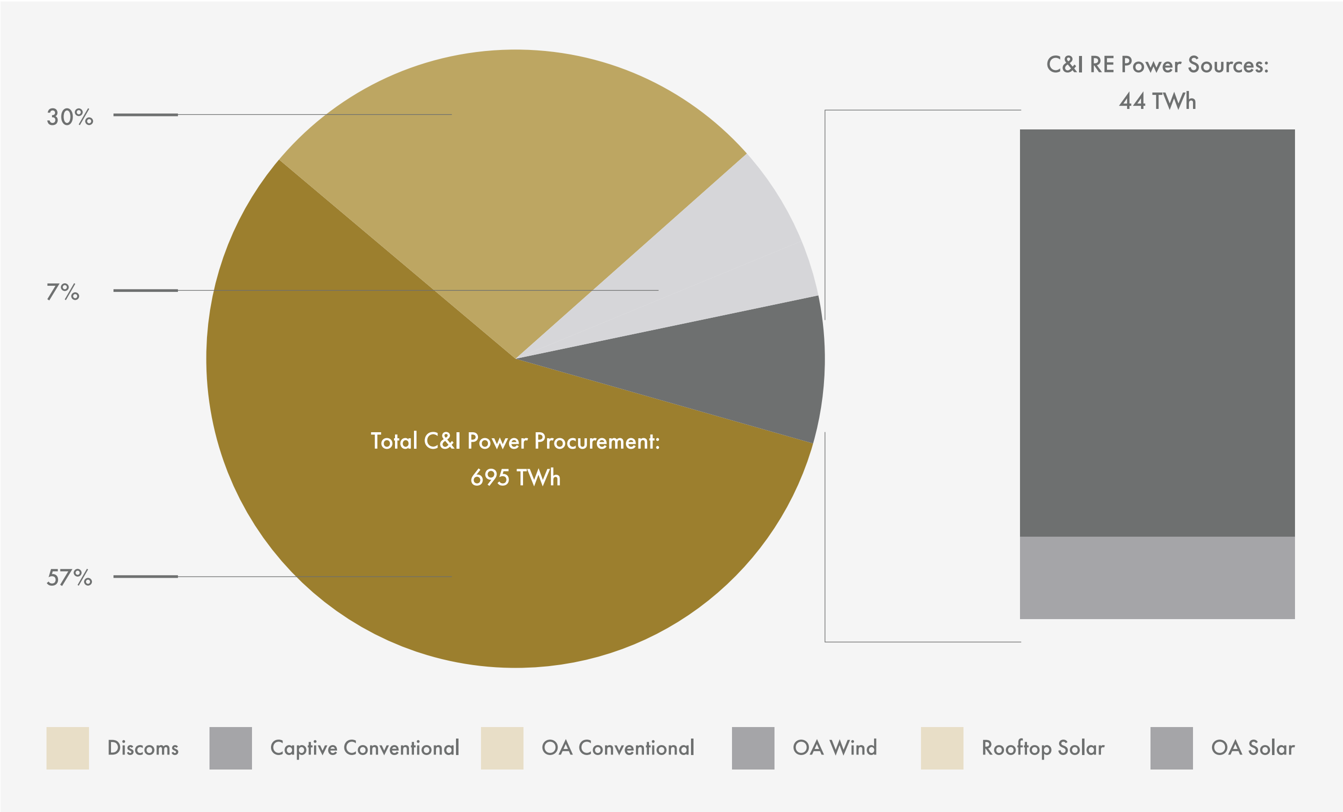
Source: India RE Navigator

Role of C&I in India's 2030 RE goals

The Indian C&I sector installed nearly 30GW of RE capacity as of 2023. Current trends in the RE mix of India's C&I sector highlight two procurement mechanisms: OA, that enables buyers to procure large-scale RE deployed off-site and RTS, that is deployed on-site. Procurement via the OA route forms the majority (nearly 75%) of the installed RE capacity procured by large corporations, while RTS represents 20% of C&I's RE mix. The majority of the OA RE comes from wind-based RE, followed by solar (Exhibit 7.6). In terms of RTS market share, C&I consumers contribute nearly 70% to the total installed capacity in the country, followed by residential consumers at around 20%.

However, this RE capacity meets only about 6–8% of the electricity demand of the country's C&I consumers (Exhibit 6). This implies that there is scope to decarbonise more than 90% of C&I's electricity consumption, which could help add about 450GW of new RE capacity in the country. The potential capacity addition can help India meet its goal of deploying 50% non-fossil-fuel power generation capacity by 2030, which requires around 500GW of new RE-based capacity. With the country aiming to deploy 50GW annually for the next five years, new RE capacity deployed by C&I consumers will play a vital role in meeting these targets, as India has awarded less than 30GW of utility-scale RE capacity in auctions annually.

EXHIBIT 7.6 **SHARE OF RE IN TOTAL C&I ELECTRICITY PROCUREMENT**

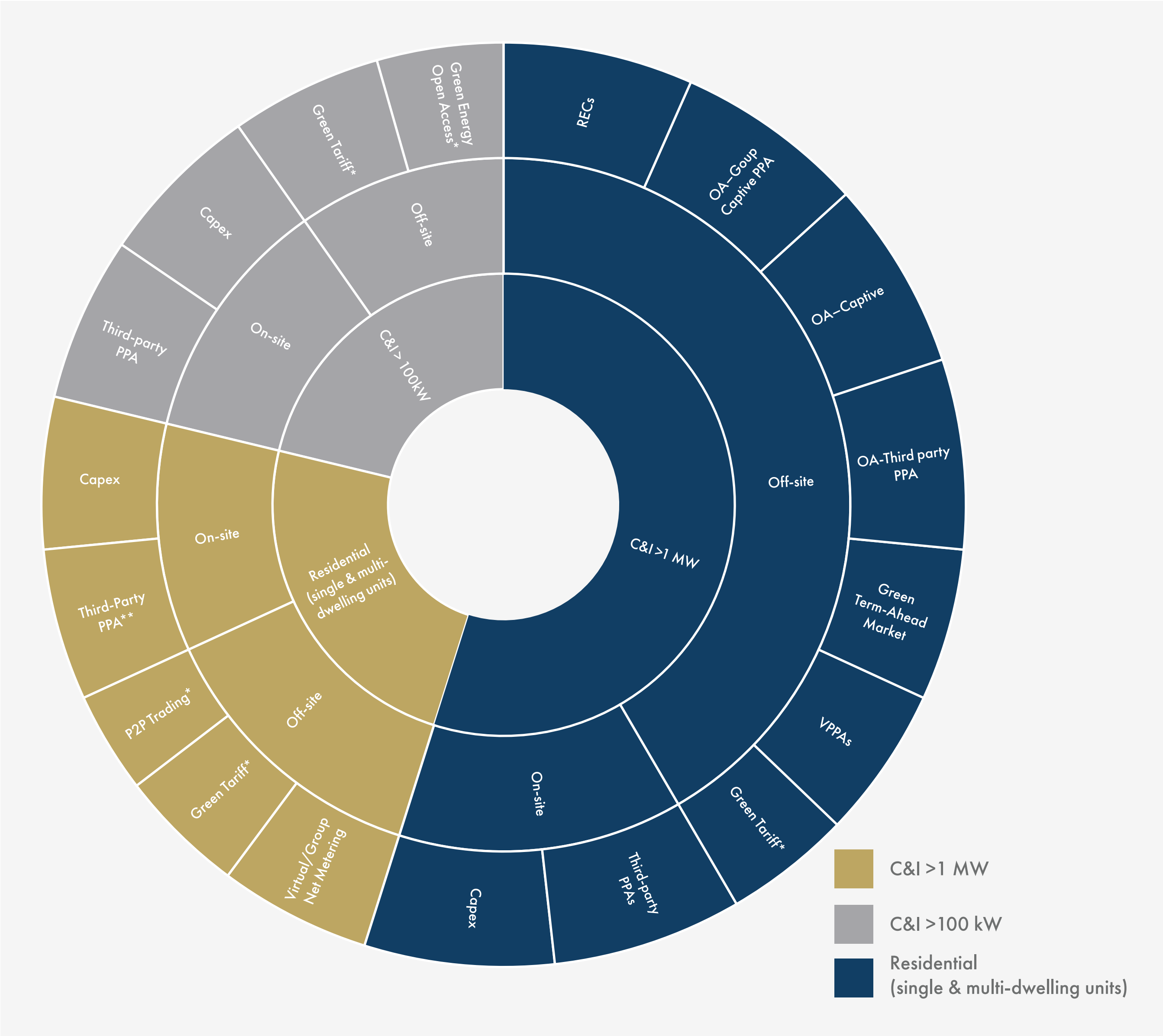


Source: Bridge to India, 2022

Existing and emerging RE procurement models

Although C&I consumers in India largely prefer OA and RTS as RE procurement pathways, multiple long- and short-term procurement models can be tapped by consumers based on their preferences. The models vary based on the nature of the consumer and location of the RE asset (on-site vs. off-site), as existing regulations restrict specific RE procurement models to particular consumer segments. Exhibit 7.7 covers the majority of the models available to key consumer segments in India.

EXHIBIT 7.7 **RE PROCUREMENT STRATEGIES**



Note: *Operational in few states.

**mostly implemented in multi-dwelling residential units

The large array of RE procurement pathways highlighted in Exhibit 7.7 provides consumers the flexibility to chart the appropriate pathway to meet their existing and future electricity demand. Each pathway offers a different set of benefits but carries specific limitations to be considered based on consumer preference. The tables highlight the different models presented in Exhibit 7.7 in long- and short-term categories and delve deep into their benefits and limitations.

Long-term power procurement options are primarily exercised via PPAs of solar and wind-based RE generators. PPAs are drawn for 10 to 25 years, wherein a buyer agrees to purchase power from an RE developer (who may own the RE asset partially or completely) at an agreed-upon tariff. RE deployment under such contracts can be off-site or on-site. Table 7.1 explores the different models in this category.

Over the years, a string of regulatory upgrades opened short-term power procurement mechanisms for customers. Short-term procurement of power consists of bilateral transactions that can be scheduled via OTC agreements between buyers and licensed traders, directly with distribution licensees or through PX. These transactions can be scheduled intraday, going up to 1 year for OTC and 11 days through the PX. Typically, RE trading makes up a small share of the total RE generated (~3%), and corporate entities form only 10–15% of the traded volumes on PX. The RE deployment in case of bilateral market transactions is always off-site. An emerging model under this category is P2P trading that can facilitate neighbourhood-scale electricity trading. Table 7.2 explores the models in this category.

TABLE 7.1 **LONG-TERM POWER PROCUREMENT MODELS**

MODELS	DEFINITION	BENEFITS	LIMITATIONS
ON-SITE			
Capex	The capital expenditure model is a self-funding model wherein consumers bear the complete capital expenditure incurred in installing the RE generator (typically an RTS system) upfront. These expenses include the equipment cost, labour, upgrades and other material costs. Future maintenance and any operational costs are also borne by the consumer.	• Consumer has complete ownership and control of the asset. • It offers the most attractive economic savings of all models. • Tax benefits in some instances.	• High initial cost of RE asset is borne by the consumer. RE may not meet 100% of the demand owing to space or contract demand limitations.
Third-party PPA	A third-party on-site PPA is a contractual agreement between a consumer who owns the premises and an RE developer who owns the RE asset and provides the sale of electricity from the asset for 10–25 years. The asset is usually fixed on the consumer's premises for the entire duration of the PPA.	• No upfront capital investment required by consumer. • Fixed electricity cost for the PPA term (10–25 years) coupled with net-metering benefits for consumers. • Low risk for consumer as developer manages the operations and maintenance of RE asset.	• Ownership of roof and electricity meter needs to be with consumer throughout contract duration. • Consumer needs to buy out RE asset to exit contract prematurely.
OFF-SITE			
Third-party PPA via OA	OA allows consumers with connected load greater than 1MW to choose their own electricity supplier. OA consumers can sign third-party PPAs for RE assets beyond their premises either within or outside the state.	• No upfront capital investment required by consumer. • Fixed electricity cost for the PPA term (10–25 years). • Low risk for consumer as developer manages the operations and maintenance of RE asset. • Consumer can meet 100% of their electricity demand with RE, as the asset is off-site and has no space constraints.	• Grid charges imposed by Discoms can shrink the economic benefits offered by low RE tariff. • Banking restrictions can lead to under-utilisation of RE asset, especially if demand and RE generation occur at different hours.
Captive/ Group Captive via OA	A captive generation plant in India may be set up by any person, co-operative society or association of persons (including companies) for generating electricity primarily for self-consumption. Multiple stakeholders can subscribe to a captive power plant through a group captive mechanism involving setting up a power plant and buying at least 51% of the generated electricity, with a minimum 26% ownership and a 10% allowable variation in consumption based on ownership shares.	• Fixed electricity cost for the PPA term (10–25 years) • Exemption from cross subsidy and additional surcharges in most states makes it more lucrative for consumers compared with third-party OA. • Consumer can meet 100% of their electricity demand with RE, as the asset is off-site and has no space constraints.	• Full or partial capital investment of consumer is needed under both models.

TABLE 7.1 **LONG-TERM POWER PROCUREMENT MODELS (CONTINUED)**

MODELS	DEFINITION	BENEFITS	LIMITATIONS
Green Energy OA (GEOA)	GEOA grants consumers and businesses unrestricted access to multiple RE sources by enabling consumers to choose electricity suppliers based on preferred renewable sources (e.g. solar, wind, hydro, biomass).	• Eligibility criteria enables consumers greater than 100kW to procure RE via OA. • Consumer can meet their 100% demand with RE, as the asset is off-site and has no space constraints.	• Only a few states have operationalised the model thus far.
Community Solar	Community solar allows a group of consumers to own a common RE asset usually deployed on an off-site location. Consumers receive net-metering benefits from the common asset proportional to their ownership of the RE asset directly on their electricity bills. The model enables consumers with limited or no roof access to adopt RE.	• Community solar is one of the only models that allow domestic consumers to access RE benefits via off-site RE assets. • Consumer can access net-metering benefits that provide maximum savings potential. • Consumer can meet their partial or complete demand as the scale of ownership of the RE asset is flexible for each consumer.	• The regulatory mechanism for community solar is operational in very few states. • Lack of project developers offering this model to consumers. • Lack of awareness about the model among consumers
Virtual Power Purchase Agreements (VPPAs) via Bilateral Transaction	VPPA is a bilateral agreement signed between the power producer (RE generator) and the C&I consumer without any physical delivery of power. Under VPPA, the power producer sells its electricity on the power exchange (such as IEX and PXIL) at the market price. The consumer only receives the RE attribute (green energy credits) associated with the traded power for a pre-agreed VPPA contract price called the strike price. However, the difference between the strike price and the wholesale market rate forms the basis of the actual price settlement between the consumer and power producer.	• No physical connection or on-site/off-site installations • Can be scaled based on consumer demand	• Regulatory and contractual complexities • Potential for cost savings is limited as the cost of VPPA is borne by consumer and offers limited or no savings on consumers' electricity demand. • Mostly offered to large commercial and industrial consumers of electricity.

BOX 7.1

Virtual Power Purchase Agreements (VPPAs)

VPPAs are gaining popularity globally as an effective way for large corporations to meet their RE targets. VPPAs allow companies to procure RE without disrupting the flow of electricity, making them resilient to changing regulations. VPPAs are regulated segments to prevent gaming or multiple trading in the United States and United Kingdom, while they are bilateral agreements without mandatory financial reporting in Canada. For India, compliance directives need to be framed for VPPAs regulated by CERC and SEBI to ensure ease of adoption for C&I consumers through single-window clearance. VPPAs generally involve monthly price settlements and accounting, with average tenure of over 10 years.

Another best practice for India is to allow VPPA projects to register under I-REC or REC, providing an advantage to multinational corporations and tapping into the international market demand. RECs assure and track the power produced by a green source, and every megawatt-hour produced by a green source earns one REC.

Examples of successful VPPAs include the Rewa Ultra Mega Solar Park (750MW) in Madhya Pradesh, India, where corporate buyers such as Mahindra Renewables, Acme Jaipur Solar Power and Arinsun Clean Energy developed 250MW each. Microsoft also signed a 15-year VPPA for 315MW of wind energy in India, and Google has signed multiple VPPAs globally. The success of these multinational corporations can encourage other customers to explore VPPAs.

It is projected that 35%–45% of the commercial and industrial customers procuring power from Discoms in India will sign VPPAs by 2030.

TABLE 7.2 **SHORT-TERM RE PROCUREMENT MODELS**

MODELS	DEFINITION	ADVANTAGES	LIMITATIONS
Green Tariff	Green tariff is a specialised retail tariff that electricity Discoms charge for the sale of RE to consumers. Consumers can sign up for this tariff from Discoms procuring electricity on their behalf from RE plants.	• No long-term commitment expected from consumers. • Easy to adopt.	• No cost savings for the consumer as the green tariff is in addition to the existing electricity tariff. • Green attributes are not transferred to the consumer. • The model is operational in a limited number of states.
Green Term-Ahead Market (GTAM)	Green term-ahead market (GTAM), a power trading platform, was launched to enable bulk electricity buyers (C&I consumers with a contracted load of 1MW or above) to procure RE on a short-term basis from merchant RE projects or Discoms having surplus RE beyond their renewable purchase obligations or RPOs through bilateral trading. It also created opportunities for project developers to develop merchant RE capacity without getting tied down by long-term PPAs. Four types of short-term contracts are covered under the GTAM: intra-day, day-ahead contingency, daily and weekly.	• No long-term commitment expected from consumer. • Flexibility in procuring electricity based on consumer need.	• Fluctuation in demand and supply can affect the price and volume of electricity significantly. • Only large commercial and industrial consumers of electricity can access GTAM.
Renewable Energy Certificates (RECs)	RECs are market-based instruments that promote RE sources and the electricity market. Each REC represents 1MWh of electricity generated from renewable sources such as solar and wind. RECs track and verify the flow of green energy into the power grid. They are also referred to as green tags, tradable renewable certificates (TRCs), RECs or RE credits. Buyers and sellers of RECs include RE generators, utilities and individuals. The trading mechanism occurs in energy markets, where buyers purchase RECs to meet RE targets or demonstrate their commitment to sustainability, while sellers offer RECs based on their RE production.	• No long-term commitment from consumer. • Easy to adopt. • Flexibility in procuring electricity based on consumer needs.	• Fluctuation in demand and supply can affect the price and volume of RECs significantly. • Only large commercial and industrial consumers of electricity can access RECs.
P2P Trading	The P2P model creates an online marketplace where prosumers and consumers can trade electricity without an intermediary at a mutually agreed price. This model is primarily deployed within the same Discom jurisdiction via localised energy trading platforms.	• Prosumer and consumer have flexibility of volume and price of RE they wish to trade. • The model can be accessed by consumers across all segments.	• Regulations on the model are issued in a limited number of states. • A few pilots deployed in the country, but the model is yet to achieve scale.

BOX 7.2

P2P Trading Model: Empowering Consumers as Prosumers

P2P trading models have the potential to transform the country's electricity landscape, allowing individuals to generate their own electricity and share surplus power. Countries such as the Netherlands, the United States, Germany, Bangladesh and the United Kingdom have successfully implemented P2P trading. For example, in Bangladesh, SOLshare's P2P trading platform connects solar panel owners with excess electricity to those without access, enabling economic growth in rural communities. In the United Kingdom, Open Utility and Good Energy's platform 'Piclo' matches consumers and prosumers every 30 minutes, providing consumption data visualisations and control over power sales. In India, P2P trading pilot projects have been conducted in Uttar Pradesh and New Delhi thus far. The success of these pilots have led to the states issuing P2P regulations.

In the coming year, Lodha plans to aggressively pursue its RE goals by testing multiple RE procurement pathways, including green energy OA and community solar for its residents.

ECONOMIC ASSESSMENT OF RE PROCUREMENT PATHWAYS

The various RE procurement pathways identified in earlier sections of the chapter cater to a wide variety of consumer needs and offer vastly different benefits. The procurement pathway and economic benefit can vary based on the consumer's electricity demand, consumption pattern and preference regarding the location of the RE generator (on-site vs. off-site), in addition to the amount of equity the consumer can deploy for the RE asset.

For C&I consumers

Electricity tariff for C&I consumers in India continues to grow consistently and is layered with multiple duties, taxes and surcharges. Exhibit 8 showcases the landed electricity tariff, including all charges imposed on a typical commercial consumer in Maharashtra. It highlights that the variable component of the electricity bill, including all taxes and duties at commercial consumers' premises, is around ₹15 per unit. More than 20% of this cost can be attributed to additional charges such as wheeling charges, electricity duties, fuel surcharges and taxes. Electricity tariff paid by consumers fluctuates across the year because fuel surcharge is typically higher during summer compared with the rest of the year.

EXHIBIT 7.8 **VARIABLE ELECTRICITY COST FOR A COMMERCIAL CONSUMER IN MAHARASHTRA**

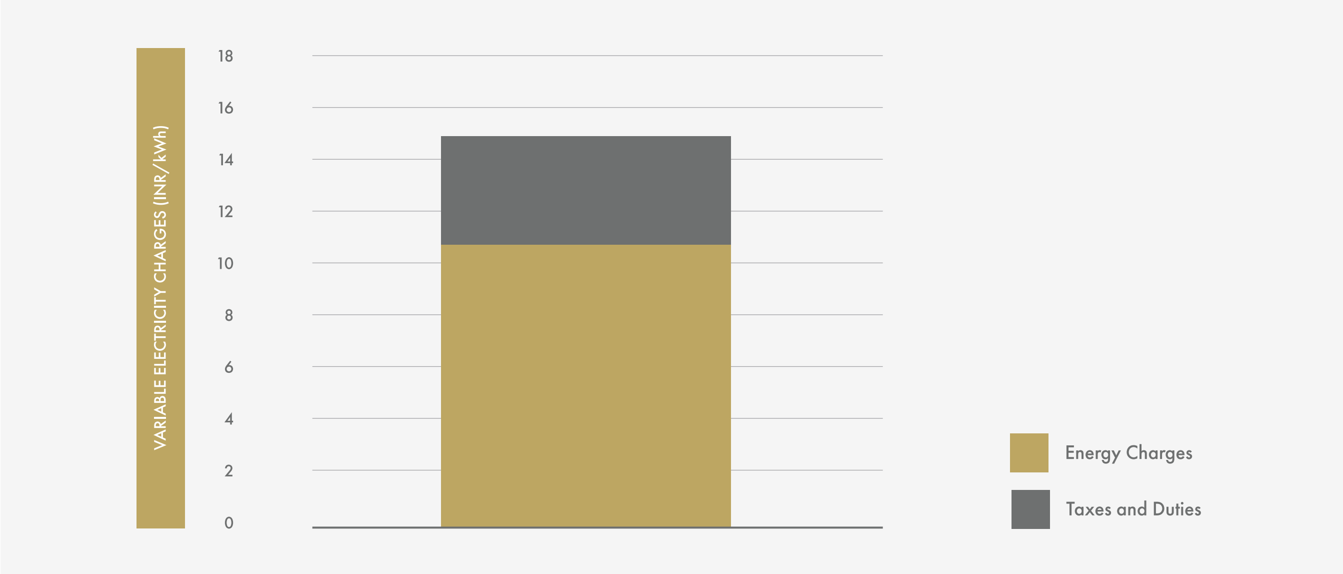
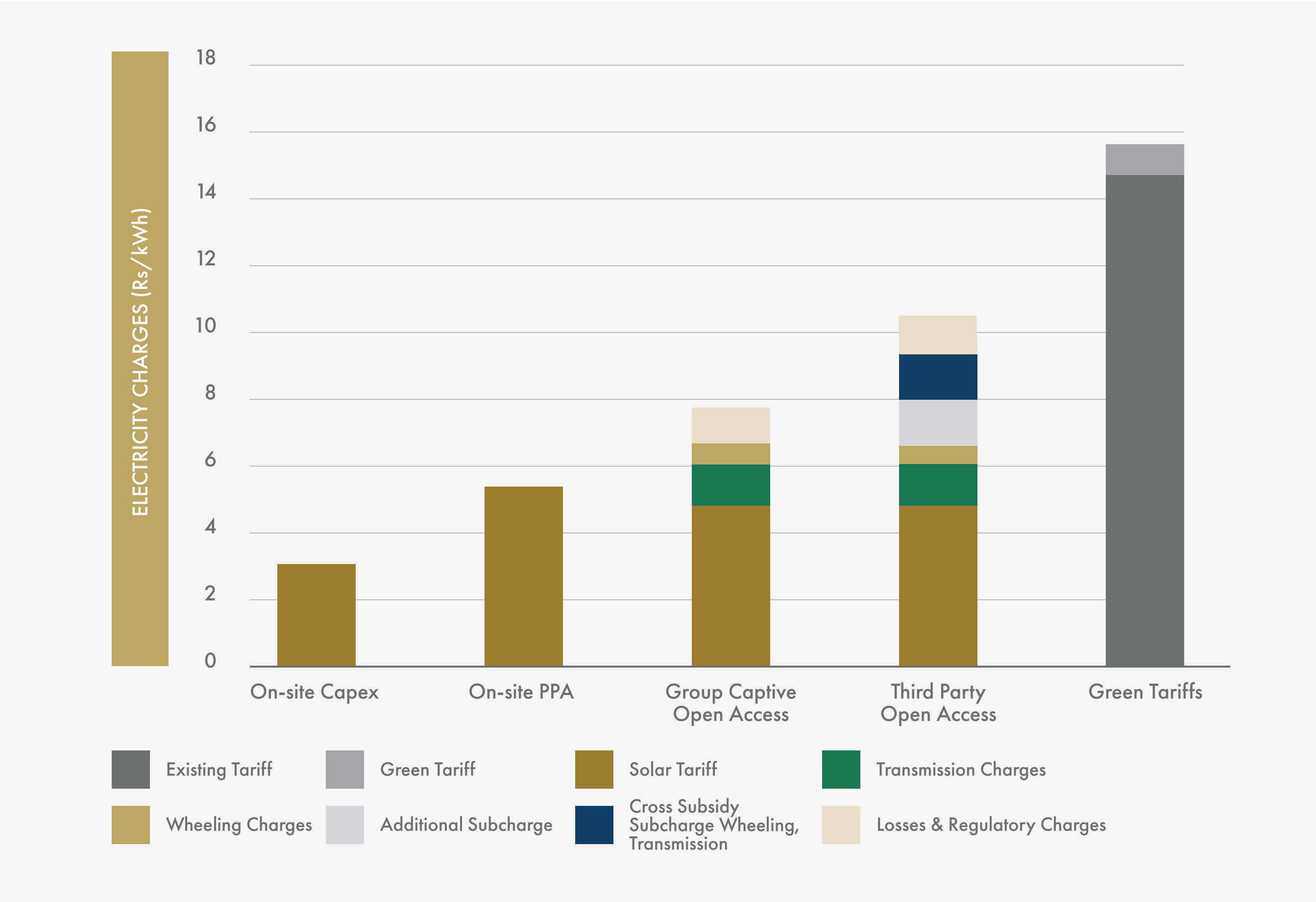


EXHIBIT 7.9 **COMPARISON OF LANDED COSTS OF VARIOUS RE PROCUREMENT PATHWAYS FOR C&I CONSUMERS IN MAHARASHTRA**



In comparison, the landed cost of the majority of the RE pathways for a typical commercial consumer in Maharashtra offers significant savings, as shown in Exhibit 7.9. The landed cost of the majority of the RE procurement pathways is around ₹5–10 per unit. On-site capex offers LCOE of less than ₹4 per unit over 25 years, making it the most cost-effective procurement pathway. In this case, consumers have the potential to save 30%–80 % of their existing variable electricity tariff by adopting RE. The key takeaway from the exhibit is that the potential for economic savings exists for commercial consumers across available pathways (except green tariff) owing to high electricity tariff and low tariff offered by RE generators.

On-site RE procurement pathways

On-site procurement models typically offer the highest economic savings owing to exemptions from transmission, wheeling and additional surcharge imposed on off-site models. Of the on-site pathways, the capex model offers the highest economic savings. Consumers can recover the majority of their equity within less than five years with net-metering benefits.

The on-site PPA pathway in this case is available at less than ₹6 per unit and offers low savings, as RE developers bake in their cost of capital and risk while offering the final PPA rate to consumers who are bound to pay this rate for the entire RE generation for 15–25 years typically.

Despite the high savings potential of on-site procurement pathways, these models are usually limited in scale by space availability or consumer's sanctioned load, as many states only permit RE asset capacities on-site to scale up to the consumer's sanctioned load.

Off-site RE procurement pathways

The landed cost of electricity for off-site RE varies significantly across different parts of the country but has largely increased over the years due to states hiking the additional charges levied on these models. However, despite offering low economic savings, off-site RE pathways offer consumers a large array of benefits, including the flexibility to choose a pathway based on the equity size the consumer can allocate to asset ownership. Consumers can also meet 100% of their electricity demand as these pathways are unaffected by on-site space constraints and sanctioned load constraints. Notably, the off-site models highlighted in Exhibit 9 currently cater to consumers with sanctioned loads greater than 1 MW in most states across India.

Among off-site procurement models, the group captive OA models offer the highest economic savings potential and the opportunity to meet 100% of the electricity demand despite the additional wheeling, transmission losses and charges, which account for about 30% of the landed RE tariff for consumers in Maharashtra. However, the consumer would have to provide partial investment of the RE asset to qualify for this pathway. Third-party OA provides a zero-investment model to consumers but the majority of the states have levied significant charges on this model, including cross subsidy charges and additional surcharges, shrinking the savings potential of OA. As indicated in Exhibit 7.9, in Maharashtra, the additional charges levied on consumers opting for third-party OA account for more than 50% of the landed RE tariff, leading to substantial reduction in the savings potential of this pathway.

Beyond third-party OA, green tariff offers a zero-investment procurement pathway and the potential to meet 100% of a consumer's electricity consumption. However, it does not offer any savings as the tariff is in addition to that being paid by the consumer.

BOX 7.3

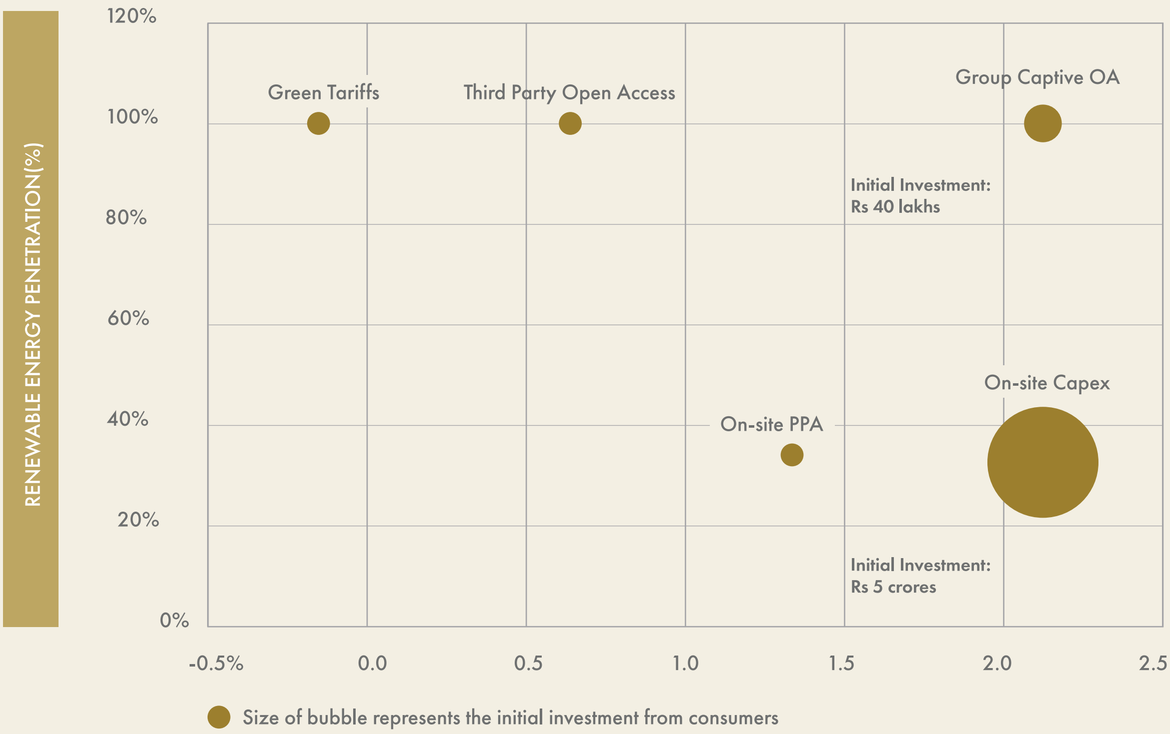
Case Study on Identifying RE Pathways for Commercial Consumers in Maharashtra

Although the landed cost of RE tariff is a key metric that drives a consumer's decision-making process, the initial investment and quantum of demand that can be met with respective pathways (RE penetration) should be considered while deciding the ideal procurement pathway.

Exhibit 7.10 showcases the electricity savings potential, RE penetration and initial investment for each procurement pathway for a commercial consumer in Maharashtra. The highest economic savings for this consumer can be achieved with the on-site capex and group captive OA pathways. However, the drawbacks associated with the on-site capex model were the steep initial cost incurred by the consumer and on-site space limitations that allowed only about 40% of the demand to be met with the on-site RE pathway.

The models that allow consumers to meet 100% of their demand with RE include green tariff, third-party OA and group captive OA. As green tariff is in addition to the existing electricity tariff, the consumer realises no savings. Savings with third-party OA are also limited owing to additional tariff highlighted in the previous section. Finally, group captive OA provides the maximum savings while meeting 100% of the demand. However, the consumer is expected to shoulder a share of the total project equity as indicated.

EXHIBIT 7.10 **ECONOMIC FEASIBILITY OF RE PROCUREMENT PATHWAYS IN MAHARASHTRA**



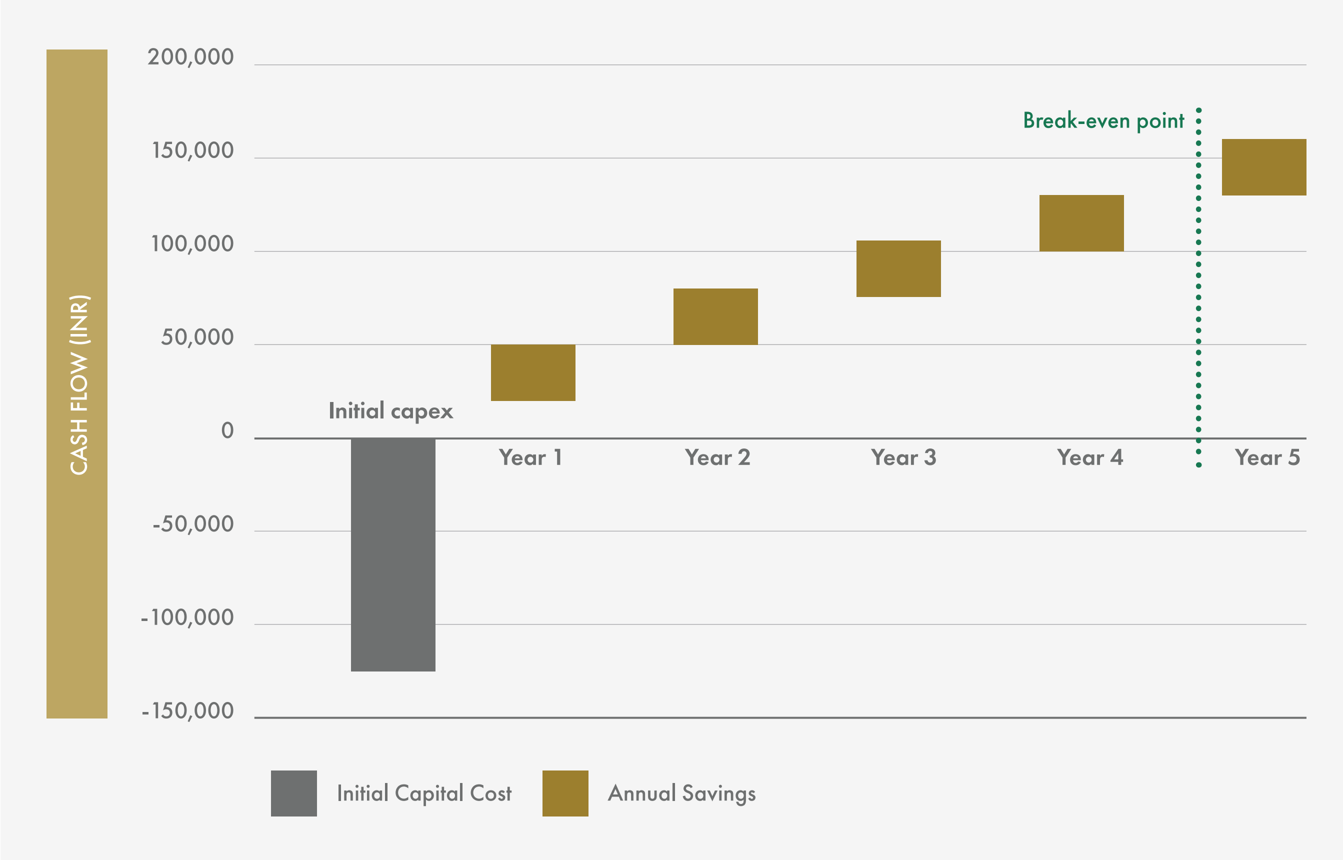
Finally, if consumers prefer pathways with zero capital investment towards the RE asset, they can opt for the following models: on-site PPA, third-party and group captive OA and green tariff. The ideal pathway among these options can be decided based on the savings and RE penetration expectations of the consumer.

A key variable to be considered is the regulatory limitations on each pathway. For example, consumers would not qualify for OA models if their sanctioned load was less than 1MW, limiting their options for on-site RE procurement pathways. Hence, measuring each pathway on multiple criteria and comparing all available pathways on those criteria can improve the consumer's decision-making.

For residential consumers (single-dwelling households)

Residential consumers in India can adopt RE primarily via RTS to achieve maximum economic savings. To help reduce the burden of the initial capital cost of the RTS system, the central government offers lucrative capital subsidies for domestic consumers of around 30% for system sizes up to 3kW and around 20% for systems up to 10kW.

EXHIBIT 7.11 **ECONOMIC ANALYSIS OF ROOFTOP SOLAR FOR A DOMESTIC CONSUMER IN MAHARASHTRA**



Source: Bridge to India, 2022

The economic analysis above highlights a simple cost-benefit analysis for a typical residential consumer in Maharashtra with an electricity consumption of 400 units per month. With a 3kW RTS system, consumers can offset nearly 90% of their electricity demand and electricity costs.

Based on the existing electricity tariff paid by residential consumers in Maharashtra, they can recover the initial capital investment for the RTS in less than five years with the annual savings generated from the net-metering benefits. These savings can be significantly higher if the electricity tariff increases.

Beyond the break-even point of the RTS system indicated in Exhibit 7.11, consumers enjoy around 20 years of free electricity from the RTS and are insulated from future electricity tariff shocks.

BOX 7.4

Need for Emerging Models for Multi-Dwelling Households

As highlighted earlier, the home-ownership dynamic in urban India is changing steadily. As existing regulations cater only to domestic consumers with exclusive roof availability, current policies relevant to RTS need to note the trends favouring multi-dwelling units and tenancy arrangements as opposed to home ownership due to the following: (a) most consumers residing in multi-dwelling households such as flats or flats do not have access to exclusive rooftop spaces, (b) tenants cannot take independent decisions about permanent installations such as RTS and (c) tenants have little incentive to foot the high investment in RTS systems. As a result, they have limited opportunities to procure RE to reduce electricity bills. The options available include green tariff and installing RTS on a shared rooftop area. However, notably, the former comes at an additional cost in the form of a green premium, disincentivising consumers to adopt this model. The latter caters primarily to common loads of the building (elevators, water pumps, common areas lighting, etc.).

The recent Energy Conservation (Amendment) Bill 2022 passed in Rajya Sabha brings new residential buildings with connected loads larger than 100kW within its ambit. This could mean these consumers would be obliged to adopt a minimum share of their electricity consumption from non-fossil-fuel resources. As the act imposes a stiff penalty for non-compliance, multi-dwelling buildings may need to adopt RE. Hence, there is a need to deploy regulations such as virtual net metering (VNM), P2P trading and group net metering (GNM), which allow multi-dwelling households to adopt new RE procurement models such as community solar.

For instance, VNM can allow a share of solar energy to individual units providing RE access to tenants with limited control over their roofs. Successful VNM implementations exist internationally in Greece, Lithuania, the United States and Australia. While a great deal of discussion centres on who benefits from solar in the United States, the country provides examples of enabling access to community solar for low-income tenants. California's community solar programme is making strides in this regard by allowing for community solar credits to be excluded from a low-income household's monthly income and, therefore, excluded from their monthly utility allowance calculation (30% of monthly income). This also points to the inter-departmental coordination required to enable equitable benefits from community solar.

Closer home, the GNM model is being deployed in Delhi to allow excess electricity from a consumer's RE generator to be adjusted in more than one electricity connection of the same consumer as long as they are within the same Discom's jurisdiction. These regulations have incentivised consumers such as HPCL, which recently issued a 10MW RE tender to meet the electricity demand for 68 retail outlets in Delhi via GNM and VNM.

Lodha aims to meet 10% of the residents' electricity demand with RE by 2025. Multiple residential societies within Lodha's portfolio have adopted solar for common building loads.

KEY CONSIDERATIONS FOR ACCELERATING

RE procurement in India has evolved significantly over the last decade. Although the sector has progressed tremendously, multiple challenges across the policy, regulatory, technical and financial aspects of RE procurement inhibit the consumer adoption of RE. Global and local advancements in RE procurement provide India an excellent opportunity to improve consumer access to RE.

Policy and regulatory

Frequently changing policy and regulatory landscape that disincentivises RE adoption

Net metering has been a crucial lever to accelerate the adoption of RTS. However, many states have tried to roll back this mechanism to varying extents. In 2019, Maharashtra considered rolling back net metering provisions for all consumers, except residential, and instead applying 'gross metering', which yields low economic benefits. Due to the severe backlash this decision faced from consumer groups, it was reversed. Uttar Pradesh reserves net-metering benefits for residential consumers only, while West Bengal limits net metering of up to 5kW for net-metering consumers.

Similar ambiguities also exist in RE pathways. Some states such as Gujarat and Rajasthan define captive consumers differently from the rest. For example, the Gujarat state government defines captive consumption such that off-takers are required to have 100% equity investment in the RE plant, making the group captive model irrelevant. In Rajasthan and Haryana, Discoms push for consumer stake in group captive projects to be the same as their share in consumption, affecting RE uptake for C&I consumers with low electricity demand.

In case of OA RE plants, the withdrawal of waivers on various charges for OA projects and increased penalties for power schedule deviation continue to affect the feasibility of RE procurement for consumers across multiple states. In fact, a recent study indicates that in a growing number of states, third-party OA charges are greater than the electricity tariff, making this model unviable in those states. These charges can significantly influence RE's consumer uptake.

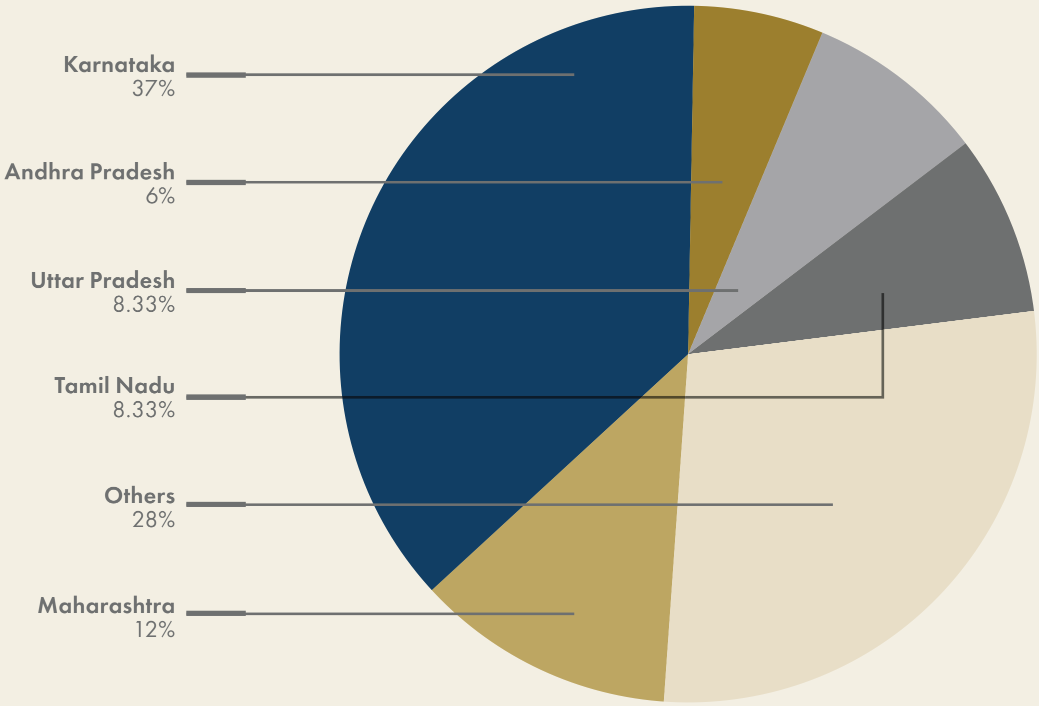
BOX 7.5

Karnataka leads RE procurement via OA

RE adoption in states with few additional charges on procurement and less stringent regulatory restrictions on banking increased significantly. The impact is evident based on the growth in OA projects over the last decade in Karnataka, which accounts for around 40% of India's existing OA capacity.

Karnataka's journey to become the leading state for OA in India can be attributed to the incentives offered by KERC in 2014. The incentives were introduced to encourage consumer uptake of RE as the state was struggling to meet its RPO levels. The incentives exempted all solar power generators deployed within the state between 2013 to 2018 from paying wheeling, banking and cross subsidy charges for OA for 10 years from the commissioning date.

EXHIBIT 7.12 **CUMULATIVE SOLAR OPEN ACCESS INSTALLED CAPACITY ACROSS STATES (%)**



The incentives triggered rapid uptake of OA solar projects as Karnataka's OA capacity jumped from 176MW in 2015 to over 3,000MW in 2023. The surge in RE deployment also led to the state exceeding its RPO obligations.

Sporadic implementation of emerging RE procurement models across the country

Only a handful of states such as Delhi and Odisha have adopted regulations to enable VNM, GNM and P2P trading that enables consumers with space constraints to benefit from RE adoption. Adoption of such models, especially in dense urban cities, can lead to high RE procurement as consumers in such cities have increased electricity consumption and limited or no roof access.

A large number of commercial, institutional and industrial consumers today cannot access OA as an RE pathway owing to existing regulations, limiting it to consumers with sanctioned loads greater than 1MW. The central government introduced the Green Energy Open Access regulations in 2022, permitting consumers with sanctioned load greater than 100kW to adopt RE via OA. Recent regulations also permit consumers with sanctioned load of 10kW and above but with aggregate loads of 100kW to qualify for GEOA. However, very few states have operationalised GEOA thus far, preventing consumers from accessing this model.

The majority of Lodha's existing electricity demand can be attributed to individual sites with contract demand less than 1MW. Owing to on-site space constraints, the group can only leverage green energy OA to adopt offsite RE. However, as Maharashtra has not operationalised GEOA as of date (September 2023), the group has adopted green tariff despite a significant rise in electricity costs to ensure their electricity demand is met by RE.

For sites where the contract demand is greater than 1MW, Lodha has the potential to save more than 50% on its electricity tariff via group captive OA.

BOX 7.6

Rise of Community Solar

With net metering phasing down across states with high solar penetration in the United States, consumers are progressively adopting solar via novel models such as community solar. This model accounted for more than 10% of the distributed generation market in 2022 and is expected to double its reach by 2030. New York has deployed more than 1GW of community solar and aims to achieve more than 10GW by 2030. By following a subscription model wherein consumers are not expected to provide the capital cost for the solar system upfront, the model caters to low-income households as well. As over 70% of New Yorkers reside in rental premises with no access to individual roofs, community solar provides a pathway for RE adoption. The rapid rise in adoption across the United States can be attributed to the majority of the states encouraging the uptake of the model, with 41 states deploying at least one community solar project. The state initiatives are complimented by DOE's bold ambition of enabling community solar for 5 million houses by 2025. Unlocking similar models in India can play a vital role, especially for consumers with limited or no roof availability.

Significant duties and levies on solar equipment

To encourage domestic manufacturing of solar modules, the GoI imposed a safeguard duty (SGD) of 15% on imported solar modules and cells. Once the SGD expired, the government imposed a 40% basic custom duty (BCD) on imported solar modules and 25% on imported solar cells. With a 10% social welfare surcharge, effective BCD rate on cells and modules would be 27.5% and 44%, respectively. However, with the domestic solar module manufacturing capabilities still at a nascent stage, the country continues to depend on imports, leading to module procurement becoming more expensive. The extra costs may result in increase in solar tariff by around 10%. Separately, the Ministry of Finance increased customs duty on solar inverters from 5% to 20% with effect from April 2021.

The volatile cost of RE components can disincentivise consumers from adopting RE as the cost competitiveness is challenged owing to additional duties and taxes.

Banking provisions

Banking provisions can provide crucial support in the proliferation of variable RE within states as it allows generators to 'bank' surplus electricity production by supplying it to the grid and withdrawing it later in the billing cycle against banking charges.

Due to the variability of RE, annual banking facilities can provide maximum benefit. However, some states such as Gujarat and Maharashtra have switched to the monthly banking facility, while a few such as Andhra Pradesh and Karnataka have withdrawn banking provisions completely. Banking is a crucial mechanism affecting a project's economic feasibility, especially for consumers using electricity in non-RE hours. With states increasing restrictions on banking, the economic benefits for consumers switching to RE to meet their needs will lower.

Constraints on RE capacity

Some states impose limits on the size of the RE system. However, caps on system sizes for net metering also range from as low as 10kW in some states to as high as 2MW. Many states impose the restriction of the RE system to the sanctioned load or contracted demand of the consumer. Twelve states in India have a net-metering cap of 500kW in place. OA RE projects in Maharashtra are limited to 140% of the consumer's contracted capacity. Such constraints prevent consumers from meeting 100% of their electricity demand from RE. This can be an acute challenge for consumers who have established RE100 goals.

FINANCING

Access to finance to incur capital or operational expenditure

Residential and MSME consumers can own an RE asset by making upfront capital investments or via financing from banks or other financial institutions. As the majority of the commercial banks and financiers perceive residential and MSME consumer-sited RE assets as risky investments owing to the loan's small ticket size, limited creditworthiness of consumers and challenges associated with presenting the RTS system as the collateral, a large gap in financing these consumer segments exists. A similar rationale also prevents solar developers from providing PPA-based models to the aforementioned consumer categories. Hence, these consumer classes need to absorb the high upfront investments associated with RE assets, which can limit uptake.

BOX 7.7

Models on Financing RE

On-bill and on-wage financing with third-party guarantors have historically made energy efficiency services affordable for low-income households. On-bill financing (OBF) allows households to finance RE installations by adding incremental repayments to their energy bills. For example, 20 states in the United States have utilities with OBF programmes. In Berkeley, California, customers can apply for loans to install RTS systems and repay them through their property tax bills. The scheme has been successful in increasing the adoption of RTS systems in Berkeley, with more than 4,000 RTS systems installed under the scheme.

In India, the UJALA scheme enabled consumers to purchase LED bulbs through monthly or bimonthly instalments in their electricity bills. The International Finance Corporation (IFC) predicts that India's on-bill financing market has the potential to reach $3.7 billion annually by 2030.

In the past, concessional credit lines such as the World Bank–SBI credit line ($625 million) and Green Climate Fund (GCF)–Tata Cleantech credit lines have helped instil confidence in lending institutions to finance RTS for large C&I consumers. Funds such as the Tata Power-SIDBI fund and the loan portfolio guarantee by the US International Development Finance Corporation (DFC) and the US Agency for International Development (USAID) specifically target the MSME segment to adopt greater RTS by leveraging concessional finance. This exemplifies the crucial role that development funding can play in unlocking finance for RTS.

TECHNICAL AND OPERATIONAL

Quality of RE components and RE installers

For solar installations, despite national standards for product certification and manufacturing facility certification, such as Bureau of Indian Standards (BIS) and the Approved List of Models and Manufacturers (ALMM) issued by MNRE, the quality of RE components and safety of projects remain a significant challenge for consumers. According to a survey of 65 RTS installations across India, more than 90% of the systems were underperforming.

The underperformance can be attributed to several factors. Most systems had damaged solar cells, which usually happens during the transportation and installation of solar panels. Many of the sites had soiling losses owing to poor operations and maintenance of RTS systems and improper cleaning practices. Many sites also suffered from shading losses due to either self-shading or tall structures near the system such as trees or nearby buildings.

Ill-equipped or inexperienced RE installers may overlook temperature and irradiance data during site analysis and install low-quality modules with inadequate weather protection. These workmanship issues do not get covered under standards for solar PV projects that address component/equipment quality. This can severely affect the operations of the system and the operational life and electricity production of the RTS system.

The lack of consumer awareness on standards and quality of components and formal enforcement of standards through audits, and the pressure to offer the lowest price by RE installers leads to standards being unmet, further leading to system underperformance.,

Hence, there is a growing need for vendor rating frameworks (VRF) that can enable monitoring, evaluation and rating of vendors in the country, which can improve the quality of RE projects deployed by consumers.

Ease of adoption

A survey conducted for corporates and small and medium enterprises (SMEs) in 2022 revealed that SMEs prefer green tariff as an RE procurement pathway due to operational ease and minimum regulatory complexity. This is validated by the findings of the parliamentary committee in 2021, which highlighted that adopting RTS is unattractive for consumers as they face complicated and time-consuming procedures coupled with delayed subsidy disbursals.

The impact of efficient net-metering processes via single window portal and timely disbursal of subsidies is a key driver of the rapid uptake of RE in Gujarat, which leads the country in terms of RTS deployment. A similar reason is cited for Australia — a global leader in RTS deployment. Many states in Australia have simplified the permitting process and streamlined building codes for consumers keen to install RTS.

FRAMEWORK FOR DESIGNING RE PROCUREMENT PATHWAYS FOR C&I CONSUMERS

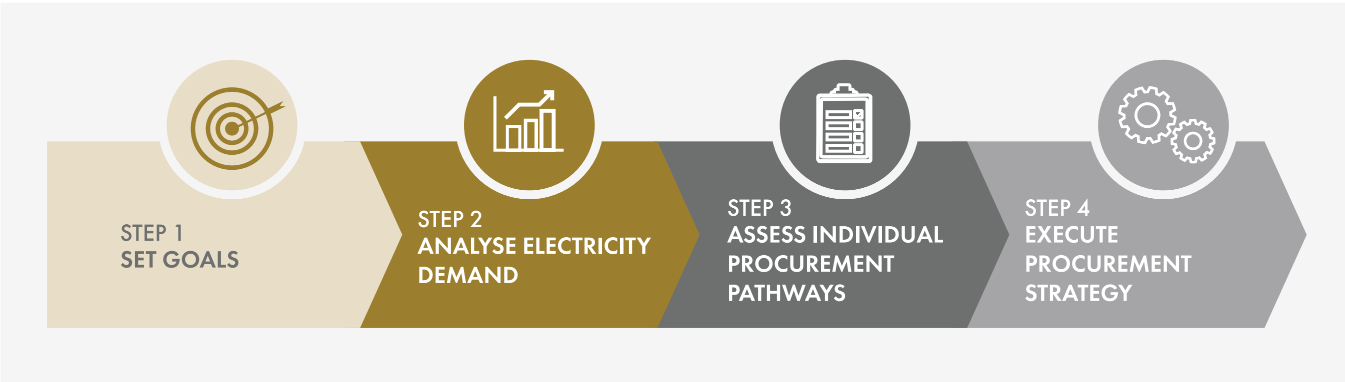
RE procurement has scaled over the last decade owing to the significant savings opportunities, ambitious net-zero targets by businesses and a concerted push by the central and state governments via renewable purchase obligations. Given the large number of procurement pathways available and limitations associated with them, it is crucial for C&I consumers to develop a framework that can help design pathways most suited for their existing and future goals.

The core components of the framework are highlighted in Exhibit 13.

STEP 1: SET GOALS

As highlighted in Exhibit 7.10, as consumers' decision on any RE procurement pathway is determined by a large number of variables, they must identify their desired outcomes and set long-term goals accordingly.

EXHIBIT 7.13 **FRAMEWORK FOR RE PROCUREMENT FOR CONSUMERS**



Source: Bridge to India, 2022

These can include the following:

1

Net-zero or clean energy goals for climate impact

C&I entities can become clean energy leaders by either obtaining green energy attributes or procuring the physical supply of RE power. Either way, consumers can set goals such as meeting a percentage of electricity demand by RE or becoming net zero by a certain year or reducing emissions associated with their electricity demand by a certain percentage.

2

Reduce cost of electricity

Consumers driven by the prospect of economic gains may want to opt for economical RE power by bypassing the expensive power from distribution utilities. Goals can be framed in terms of reducing expenditure on electricity consumption by a certain monetary or percentage figure in a timebound manner.

3

Meet additional operational requirements through RE

Consumers may simply want to secure electricity for new or enhanced operations by RE. Once the larger timebound goal by the consumer is established, setting interim goals leading to the larger goal plays a critical role and must be established by classifying the larger target into annual targets with specific RE pathways associated for individual annual targets. Consumers can also set multiple long-term goals (for example, meeting 100% of their electricity demand while lowering existing electricity costs), but it is important to filter annual procurement pathways that help meet these goals.

BOX 7.8

Growing Global Corporate Action Towards RE Adoption

The pursuit of climate impact is leading global corporates to transition to clean and sustainable practices. This includes becoming members of global initiatives such as the Science Based Targets initiative (SBTi), RE100 and Carbon Disclosure Project (CDP) and pursuing associated activities. Consumers can independently work towards reducing emissions by opting for energy efficiency, switching to electric mobility and improving resource management.

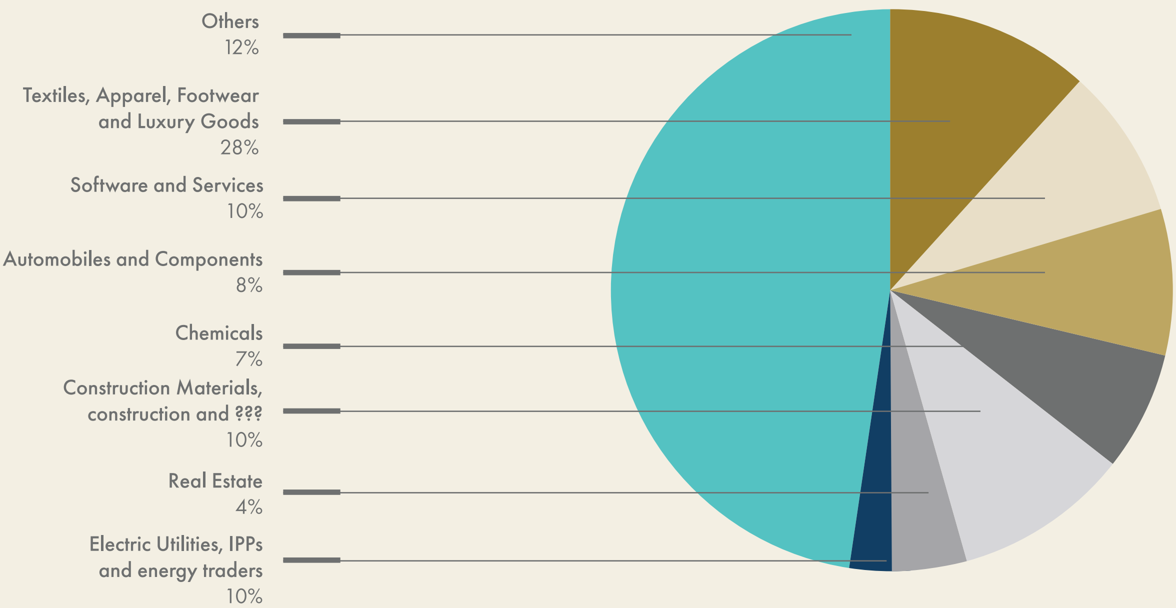
One of the most used levers for decarbonisation is procuring electricity sourced from RE sources. Over 60% of the 400 companies that announced 100% RE procurement targets globally are headquartered in Asia-Pacific. In 2022, India featured as the second largest market for

RE procurement contracts and, together with the United States, comprised nearly half of the total market share. India benefited from reforms around OA regulations, which help facilitate corporate PPAs with RE developers and can be key to meeting the increasing demand from industrial sectors.

The majority of the top 100 companies listed on India's National Stock Exchange (NSE) report emissions annually and are committed to reducing them. According to the SBTi database, 193 Indian companies are part of their initiative, with 65 companies setting net zero commitments. Textile, software and services and real estate are the major sectors that have made such commitments (Exhibit 7.14).

STEP 2: ANALYSE ELECTRICITY DEMAND

EXHIBIT 7.14 **INDIAN CORPORATE CLIMATE COMMITMENTS BY SECTOR**

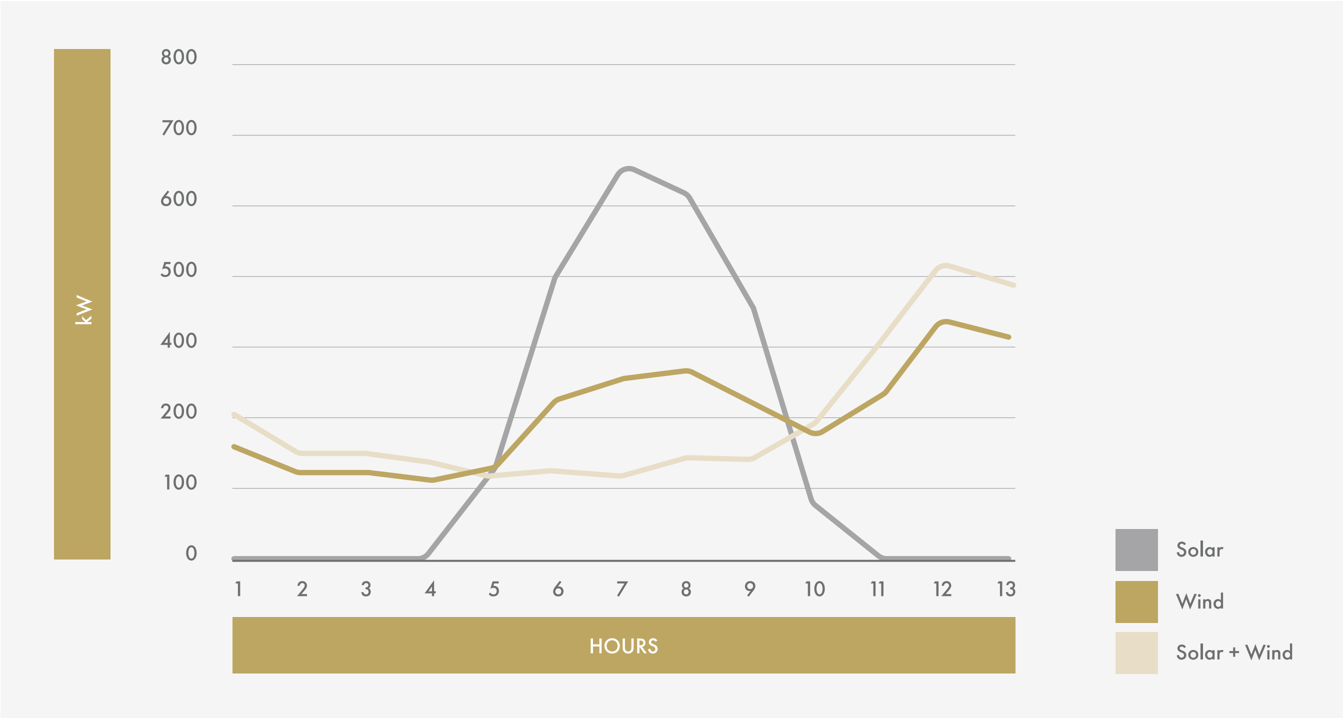


A critical step towards planning RE procurement is to analyse electricity consumption for individual sites. The ideal RE procurement pathway for an individual site or an aggregated group of sites begins with identifying the annual electricity demand for each site. This can help reveal the scale of demand that can be met via on-site RE deployment and the need for off-site RE deployment.

It is also important to assess the site's hourly, daily and monthly demand profiles to understand the electricity consumption pattern. This can help determine the appropriate resource mix for procurement. For instance, sites with high electricity demand during the day hours can benefit from solar-based RE procurement models but sites with higher electricity demand during non-solar hours may find wind-based RE procurement models more lucrative. Some sites may benefit from a blend of solar, wind and, in some cases, battery energy storage systems (BESS) to match RE procurement supply with demand. The importance of matching demand with supply will continue to grow as regulations around banking of RE are becoming more restrictive in many states and can erode the economics of RE procurement significantly.

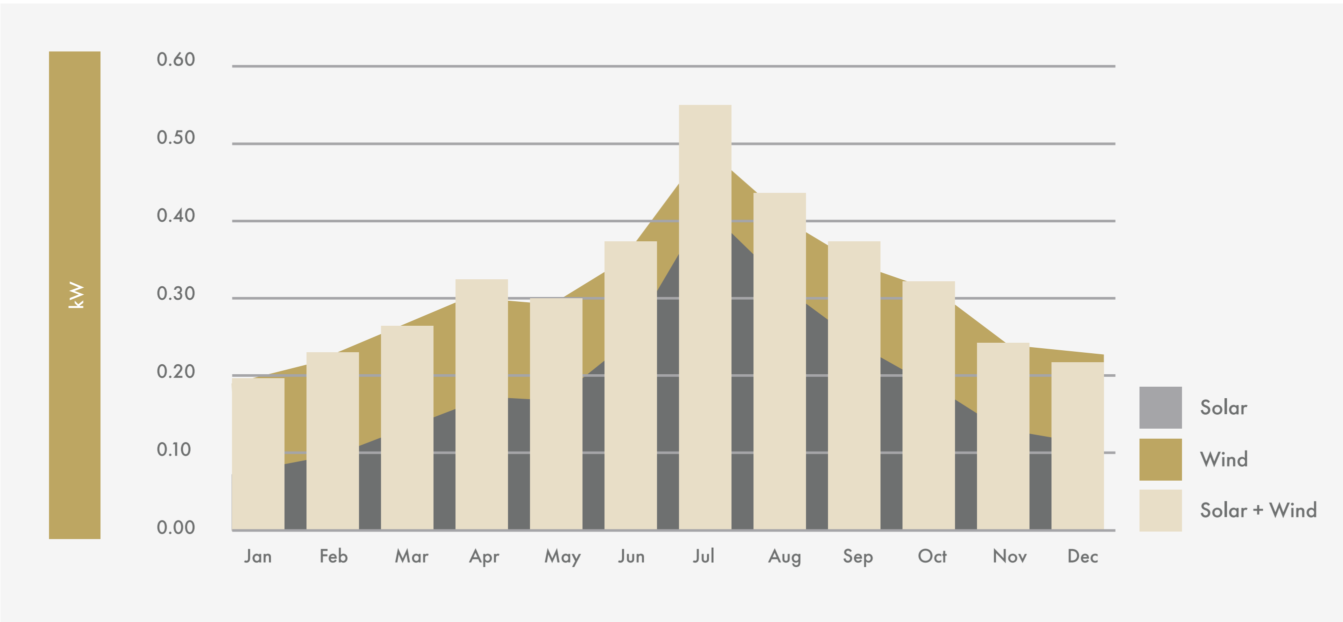
Exhibit 7.15 indicates the complementarity of solar and wind generation for a typical summer day from solar, wind and hybrid generators for a typical site in Rajasthan. Similarly, Exhibit 7.16 illustrates the seasonal variance of solar, wind and hybrid generators for a typical site in Rajasthan. Matching the load curves with generation curves provide maximum economic savings for consumers.

EXHIBIT 7.15 **TYPICAL POWER GENERATION PROFILE (DAILY)**[V]



Source: Bridge to India, 2021

EXHIBIT 7.16 **TYPICAL POWER GENERATION PROFILE (MONTHLY)**[VI]



Source: National Institute of Wind Energy

BOX 7.9

Emergence of Distributed Solar and Battery Energy Storage Systems (BESS)

Globally, the momentum to couple grid-connected solar with battery energy storage systems (BESS) at the distribution network level is increasing despite their unit cost being higher than centralised generators. This growth can be attributed to the great locational value that distributed solar and BESS can provide when deployed at the right location and triggered when the network is operating at peak capacity.

Distributed solar and BESS find the highest locational value in pockets of the grid witnessing frequent congestion and short-duration demand peaks that strain the distribution network. These pockets are prevalent in cities with high urban density where centralised generators are unable to provide localised value to the distribution network.

Discoms facing peak loads and network congestion can defer the investments needed for grid infrastructure, reduce distribution losses and improve grid resiliency with distributed solar and BESS cited close to demand centres. With BESS, consumers can utilise additional solar generation produced across the day during the evening hours. This is particularly attractive for consumers paying a time-of-day-based tariff and consumers who cannot access net-metering benefits owing to state regulations. With a BESS asset, consumers are also insulated from grid outages.

California provides a noteworthy example of leveraging regulations to influence the development of distributed solar and BESS systems. The state's first net energy metering (NEM) programme compensated consumers at the retail electricity rate for the export of solar energy to the grid, leading to a rise in the residential RTS capacity by nearly four times in the last decade. However, the recent net energy metering (NEM 3.0) regulations indicate about 60% lower savings for consumers adopting RTS compared with earlier regulations over a project's lifetime.

The new regulations, however, incentivise consumers to adopt RTS with BESS and offer a faster payback than an RTS-only system. Consumers can avail of these benefits by storing the excess solar generation during the day and utilising the same during evening hours when the time of use rates are higher. Increasing BESS penetration on the network will also enable better grid management, especially during peak hours.

Lodha is assessing the feasibility of integrating distributed scale BESS at its existing demand centres with solar generators. This can help unlock the potential of grid-interactive buildings powered by RE in India.

STEP 3: ASSESS INDIVIDUAL PROCUREMENT PATHWAYS

Based on consumer goals and demand assessment, the outline for site-specific procurement pathways can be established. As indicated in the previous sections, procurement pathways can be prioritised based on various decision variables that meet the organisational goals of either large clean energy deployment, or record the most economic benefit, or both. It is crucial that each pathway be assessed based on multiple facets, including technical, economic, financial and regulatory variables.

For on-site generation pathways, it is important to verify the billing mechanisms permitted by the respective state, as many states allow other mechanisms such as gross metering and net billing instead of net metering for different consumer classes. These solutions offer lower economic benefits to consumers than net metering and should be assessed.

STEP 4: EXECUTE PROCUREMENT STRATEGY

At this stage, a decision on the ideal procurement strategy can be reached by blending the assessment of each pathway with the demand assessment of the individual site and the consumer's long- and short-term goals. The strategy can be executed by issuing a standardised procurement document or procurement proposal across multiple RE developers. Consumers with a portfolio of sites can explore the potential of aggregating sites while requesting proposals to achieve competitive offers from RE developers owing to economies of scale. As RE pathways are adopted for more than 10 years, negotiating key contractual variables such as landed tariffs for the contract duration, performance guarantees, operation and maintenance responsibilities of the developer and PPA exit clauses should be conducted prior to execution. Finally, it is good practice for consumers to consistently monitor the performance of the RE asset after its commissioning.

For C&I consumers unfamiliar with manoeuvring the RE procurement process, it is recommended a team or taskforce be developed to design the framework proposed above. This team can include RE, finance, legal and procurement specialists from within the organisation or contracted externally to monitor the progress of RE assets. Alternatively, this work can be outsourced to agencies specialising in developing RE procurement for consumers.

Lodha follows the framework described in this chapter. Its team of consultants work alongside in-house technical and procurement experts to design and execute procurement strategies. Setting a goal of meeting 100% of its demand with RE by 2025 without paying a premium helped the group filter out pathways such as green tariff and VPPAs that prevent cost savings. The group also assesses the electricity demand across the year for individual sites and designing pathways on a site-specific basis that ensures cost savings and all of the electricity demand to be met by RE.

CONCLUSION

This section apprises consumers interested in adopting RE about the landscape of RE procurement and the different facets that would influence their procurement strategies. While operating as a consumer in a constantly evolving RE context can be daunting, the information provided above simplifies the costs, benefits, challenges and opportunities associated with each pathway and provides a framework for consumers to design their RE procurement strategies.

There is a clear case for C&I and domestic consumers in the country to procure RE. This needs to be supported by a favourable environment of policies, regulations and incentives that influence the economics of various RE procurement mechanisms. In the run-up to India's 2030 goals of meeting 50% of its electricity demand through non-fossil-fuel sources, the C&I consumer segment stands to contribute significantly through considerable RE adoption.

Moreover, the RE potential of the residential consumer segment needs to be leveraged by testing and employing new models and supporting regulations and enabling retail finance to encourage their RE adoption aspirations. At the same time, an all-round upgrade of the RE ecosystem and the technical and operational practices therein can vastly improve the speed and scale of adoption.

There are signs to signal innovation in RE procurement mechanisms with VPPAs for large C&I consumers and green energy OA, community solar and P2P trading catering to small consumers, including the residential segment.

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