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Transforming the Built Environment in Odisha through Sustainable Building Materials

BASELINE ASSESSMENT OF AFFORDABLE HOUSING SECTOR IN ODISHA

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Baseline Assessment of Affordable Housing Sector in Odisha

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List of Abbreviations

AP	Andhra Pradesh
AQI	Air Quality Index
BASUDHA scheme	Buxi Jagabandhu Assured Water Supply to All Habitations scheme
BDA	Bhubaneswar Development Authority
BDPA	Bhubaneswar Development Plan Area
BEE	Bureau of Energy Efficiency
BIM	Building Information Modelling
BIS	Bureau of Indian Standards
BMTPC	Building Materials & Technology Promotion Council
BMC	Bhubaneswar Municipal Corporation
BPGY	Biju Pucca Ghar Yojana
BSUP	Basic Services to Urban Poor
C&D	Construction and Demolition
CAGR	Compound Annual Growth Rate
CDP	Comprehensive Development Plan
CHCs	Community Healthcare Centres
CPCB	Central Pollution Control Board
CPWD	Central Public Works Department
CSEB	Compressed Stabilized Earth Blocks
DRI	Disaster Risk Index
DTP	Directorate of Town Planning
EIA	Environmental Impact Assessment
ECBC	Energy Conservation Building Code
ENS	Eco Niwas Samhita
FAR	Floor Area Ratio
FSI	Floor Space Index
FY	Fiscal Year
GA	Goa
GAD	General Administration Department
GDP	Gross Domestic Product
GCoM	The Global Covenant of Mayors for Climate & Energy
GJ	Gujarat
GPP	Green Public Procurement
GRIDCO	Grid Corporation of Odisha
GRIHA	Green Rating for Integrated Habitat Assessment
GSDP	Gross State Domestic Product
GST	Goods and Service Tax
GSVA	Gross State Value Added
HDI	Human Development Index
HP	Himachal Pradesh
HUDCO	Housing & Urban Development Corporation Ltd.
HUDD	Housing and Urban Development Department
ICLEI	International Council for Local Environmental Initiatives
IDFS	Infrastructure Development Fund Scheme
IGBC	Indian Green Building Council
IPHS	Indian Public Health Standards
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
KBK districts	Koraput, Bolangir and Kalahandi districts
KL	Kerala
KN	Karnataka
LEED	Leadership in Energy and Environmental Design
LFPR	Labour Force Participation Rate
LIG	Lower Income Group
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MH	Maharashtra
MLA	Members of the Legislative Assembly

MLALAD	Member of Legislative Assembly Local Area Development Scheme
MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoP	Ministry of Power
MP	Madhya Pradesh
MPI	Multidimensional Poverty Index
MT	Million tonnes
MUKTA	Mukhyamantri Karma Tatpara Abhiyan Yojana
MW	Megawatt
NBC	National Building Code
NBO	National Buildings Organisation
NABARD	National Bank for Agriculture and Rural Development
NGO	Non-Governmental Organisation
NITI Aayog	National Institution for Transforming India
NIUA	National Institute of Urban Affairs
NSPGY	Nirman Shramik Pucca Ghar Yojana
ODA	Pdsha Development Authorities
ODF	Open Defecation Free
OES	Odisha Economic Survey
OMBADC	Odisha Mineral Bearing Areas Development Corporation
OSHB	Odisha State Housing Board
OSDMA	Odisha State Disaster Management Authority
OSRTC	Odisha State Road Transport Corporation
OWSSB	Odisha Water Supply and Sewerage Board
PHCs	Primary Healthcare Centres
PHEO	Public Health Engineering Organisation
PMAY	Pradhan Mantri Awaas Yojana
PPP	Public-Private Partnership
PTGs	Particular Tribal Groups
PVC	Poly vinyl chloride
RERA	Real Estate (Regulation and Development) Act
RJ	Rajasthan
RPWDA	Rights of Persons with Disabilities Act
SAPCC	State Action Plan on Climate Change
SDG	Sustainable Development Goal
SETU scheme	Socio-Economic Transformation and Upliftment scheme
SK	Sikkim
SRC	Special Relief Commissioner
TN	Tamil Nadu
TCPO	Town & Country Planning Organisation
UHI	Urban Heat Island
UCLG	United Cities and Local Governments
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNNATI	Urban Transformation Initiative
UPHCs	Urban Primary Healthcare Centres
USD	United States dollar
VIMSAR	Veer Surendra Sai Institute of Medical Sciences and Research
WATCO	Water Corporation of Odisha
WB	West Bengal
WODC	Western Odisha Development Council
WRD	Water Resources Department
WRI	World Resources Institute
WWF	World Wide Fund for Nature

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A large pile of coarse aggregates, a key local building material in Bhubaneswar

Executive Summary

With increasing urbanisation, the buildings and construction sector represent 38% of total energy-related emissions, with almost 10% indirect emissions from materials (GlobalABC, 2020), of which approximately three-quarters are attributable to the buildings' operations while a quarter by the carbon embodied in their materials. Studies suggest that in the current Indian scenario, this component of embodied carbon may be as high as 40% (AEEE, 2022).

Besides the carbon impacts, the sector has severe implications for virgin resource extraction and consumption. Global material use is projected to more than double by 2060, and one-third of the total will be used in the building and construction sector. In India, the total material consumption rose to 7.42 billion tonnes by 2015 and is likely to rise rapidly till 2035 before plateauing (GIZ-TERI-DA-IFEU, 2015). Data from the UN International Resource Panel shows that non-metallic minerals had the largest share in 2019 (45.6%), with 98.2% of this for use in construction. Considering the massive scale of construction activity required to meet the needs for affordable housing in India, the building materials used in the coming years will become significant drivers of the production and consumption patterns for natural resources.

There is an opportunity for India to integrate decarbonisation strategies and circular economy principles in affordable housing development to meet sustainability standards and achieve high environmental performance in the built environment. This approach can simultaneously help generate livelihoods and new economic opportunities through innovative business models and productive utilisation of available secondary resources from industrial wastes, agricultural wastes, and construction and demolition waste.

Further, by aligning with ongoing initiatives at the national level, including Mission LiFE, PMAY, CITIIS, Smart City Mission, and others at the subnational level (such as Jaga Mission, Shakti Mission, Mukta Mission in Odisha), India can pioneer new holistic models of sustainable, affordable housing development based on localised, participatory approaches and meet its commitments towards SDGs 7, 8, 9, 11, 12, 13 and NDCs.

About the Project

This global project is supported by the Federal Ministry for Economic Cooperation and Development of the Government of Germany (BMZ) and implemented and administered by the UN Environmental Programme. The target geographies for the project include India and Bangladesh in South Asia and Ghana and Senegal in West Africa between 2022 and 2025. In India, the target states are Odisha and Maharashtra and Development Alternatives is the technical partner leading project activities.

The project seeks to address the gaps in the construction sector value chain to assist in transforming the supply and demand side bottlenecks and transition to low-carbon pathways for the sector by developing a sustainable building materials market in Indian states. This approach is aligned with the draft national-level roadmap currently under development by the Bureau of Energy Efficiency for mainstreaming energy efficiency in residential buildings.

Odisha – State Overview

Nestled on the eastern coast of India, Odisha is a state celebrated for its captivating blend of diverse landscapes and rich cultural heritage. Its geography showcases a stunning contrast between coastal plains, lush forests, and rolling hills, offering an enchanting tapestry of natural beauty and a bounty of rich mineral reserves that have propelled its industrialisation journey. The state has established a definitive identity in recent years with commendable strides in social welfare initiatives, focusing on healthcare, education, women's empowerment and the upliftment of marginalised communities. It has, however, also been affected by its high vulnerability to natural disasters.

Various state-level initiatives have led to tangible improvements in its performance on various human development indices, with an HDI index of 0.618 in FY 17-18 (MoSPI, 2019) falling in the medium HDI category. The State ranked 21st among Indian states in the 2021-2022 SDG India Index, with best performance in SDG 13 and 14. The state also demonstrates progressing performance in SDG 2, 3, 4, 5, 6, 7, 11, and 12. With a high score on the Disaster Resilience Index, the state is highly vulnerable to natural calamities like cyclones, floods, and droughts, for which it has taken active measures to mitigate disaster-related losses and improve disaster response. The state's high vulnerability to natural disasters emphasises the need for a highly resilient built environment to mitigate and avoid disaster-related risks and losses. Odisha's industrialisation has been significantly fuelled by its abundant mineral resources. With vast reserves of iron ore, coal, bauxite, and other minerals, Odisha is pivotal in supporting sectors such as steel, aluminium, and power generation nationally. This mineral wealth has boosted industrialisation within the state and solidified Odisha's status as a crucial player in India's resource-driven economic landscape.

Housing and Urbanisation – Policy and Financial Landscape

India's building and construction sector operates under comprehensive national regulations ensuring safety, quality, and environmental compliance. The National Building Code (NBC) offers guidelines on materials, design, and safety, widely adopted by local authorities. The Real Estate (Regulation and Development) Act, 2016 (RERA) ensures transparency and consumer protection, mandating project registration and fair practices. Environmental regulations involve acts like the Air and Water Pollution Acts, with the Environmental Impact Assessment (EIA) Notification 2004 requiring government clearance based on strict criteria. Additionally, building bye-laws, set by local authorities, govern specific construction aspects in their jurisdictions.

Urbanisation trends in Odisha reflect the broader shifts occurring across India. While the urbanisation pace in Odisha is slow compared to other States, larger urban centres in the State, like Bhubaneswar and Cuttack, have witnessed rapid growth, attracting investment and infrastructure development. According to Census 2011, out of the state's total population, 16.69% live in urban areas.

Bhubaneswar, the state's capital, has experienced substantial urban growth due to in-migration and its emergence as a trade, commerce, technology, and education centre. This urban expansion has led to the transformation of land use, with agricultural and forest lands being converted for urban purposes. Over the past decade, around 15,000 hectares of agricultural land was converted to residential land in Khorda district (Bhubaneswar). Urbanisation reduced forest area from 90.27% in 1970 to 62.72% in 2005. The Built-up area increased by approximately 24%, while vegetation cover decreased by around 16% during this period. Rapid urbanisation and land use changes have led to about a 1.8°C warming in Bhubaneswar compared to non-urban areas.

As per the Comprehensive Development Plan for Bhubaneswar Development Plan Area (BDPA) for 2030,[1] the BDPA population is estimated to grow from 1.37 million to 3 million, raising a need for more than 3,66,295 housing units by 2030, adding to an existing backlog of around 15,220 dwelling units. The future housing requirements, existing housing backlog, obsolescence, and currently existing non-standard housing units collectively raise the total estimated **BDPA housing requirement in 2030 to over 4,30,000 dwelling units**, of which approximately 1,55,000 units are to be developed for the LIG and EWS category.[2] This growing demand has huge implications for the housing sector with respect to its material and carbon footprint.

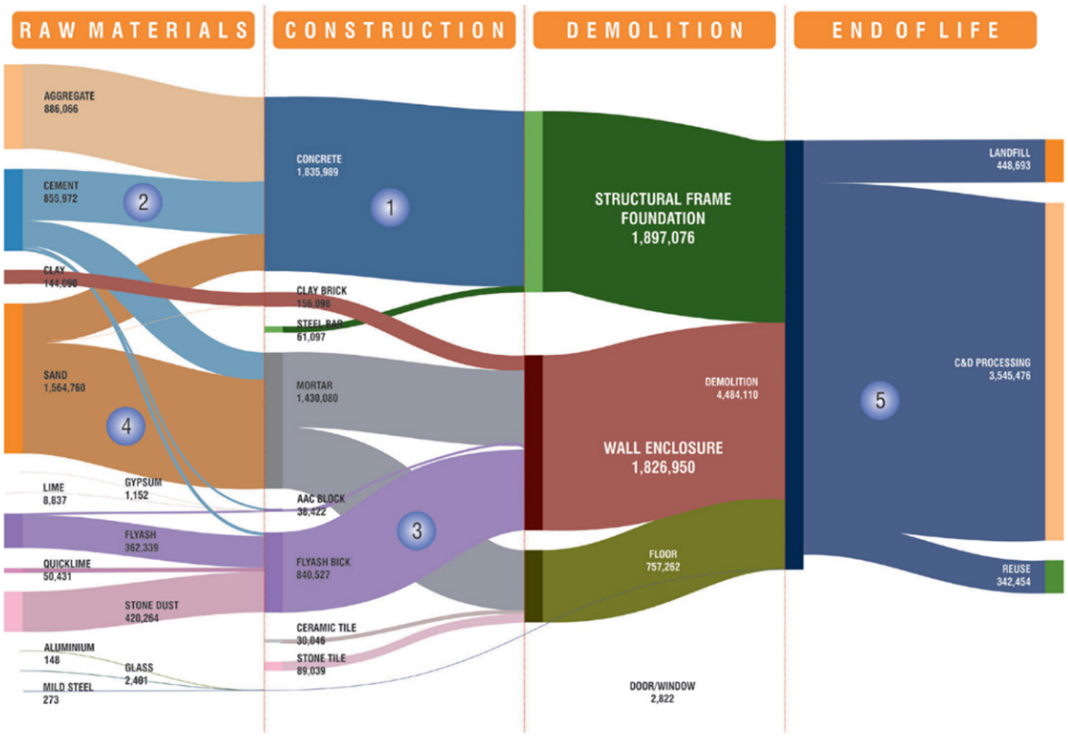
It is projected that the overall consumption of building materials, including cement, steel, bricks, and aggregates, to fulfill the requirements of the affordable housing sector of Bhubaneswar will reach over 14.11 million tonnes by 2030, leading to almost 49.83 (MJ) million tonnes of CO_2e embodied energy emissions. Calculated as per market data, in a typical G+4 affordable housing complex model in Odisha covering 1291.68 square meters, essential construction materials include concrete, bricks, sand, aggregates, cement, and steel. Bricks comprise 35% of the total construction material, while RMC contributes 30%. Sand constitutes 15-20% due to its use in concrete and bricks, cement-based units, and mortars. Aggregates and cement contribute 5-8% and 15-18% respectively. Mineral-based materials like cement and steel collectively account for 16-18% of the total flow, emphasising the significance of these materials in sustainable construction practices. Steel (50% of the total Embodied energy emissions- 20 Million tonnes), despite low usage, contributes to 50 percent of the embodied energy efficiency at 20 million tonnes making it a significant carbon emitter in current construction practices in Odisha. Whereas, highly utilised fly ash bricks accounts for only 14% of the total Embodied energy

1 The Bhubaneswar Development Planning Area (BDPA) constitutes 58 percent of the Bhubaneswar Cuttack Urban Complex (BCUC). The BDPA comprises of administrative areas, Bhubaneswar Municipal Corporation (BMC), Khurda, Jatani, and BDA rural

2 https://www.orissalinks.com/bigfiles/Draft%20Proposal_CDP%20BDPA-2008/Chapters/Chap7-Housing%20&%20Slum.pdf

Figure 1: Resource flow in construction sector of Bhubaneswar based on an analysis of 2179 residential buildings in Bhubaneswar with 1.6 million sqm built-up area

Source: (Khannam, Sinha, Sen, & Goswami, 2020)



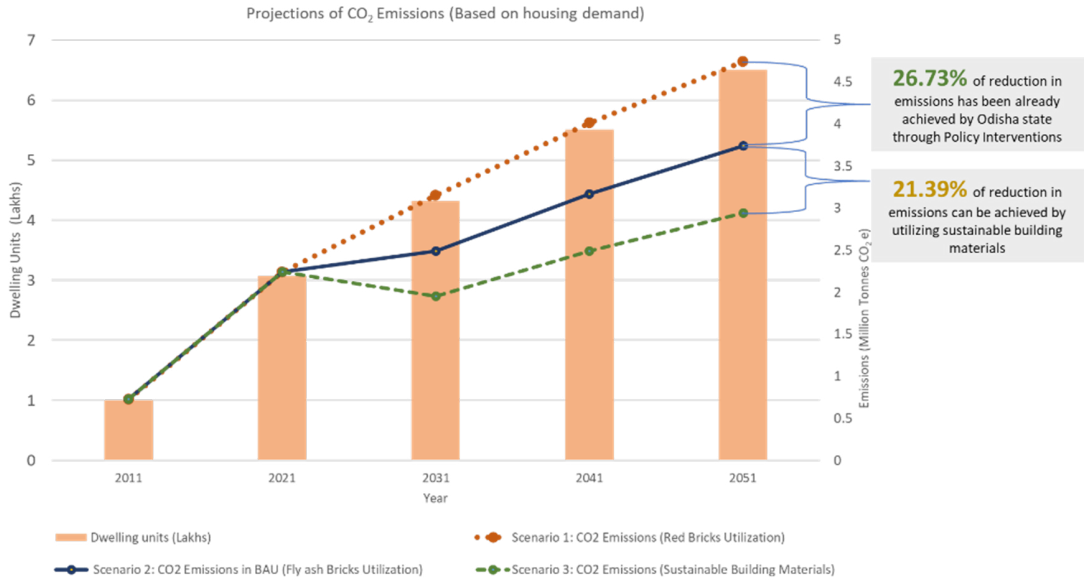
emissions at 3 Million tonnes. Transitioning from red clay bricks to fly ash bricks in Odisha represents a significant step towards sustainable and eco-friendly construction practices, which helped the state save approximately 200 tonnes of CO_2 emissions.

Considering the type of building technologies deployed in Odisha, the carbon footprint is estimated to be 0.94 tonne of CO_2 equivalent per sq. meter. For the precast technology construction (EPC Model) with a total area of 1477.79 sq. meters, emissions are estimated at 1389.11 tonnes of CO_2e. In the framed structure (PPP Model) covering 1291.68 sq. meters, emissions stand at 1214.17 tonnes of CO_2e (George & Jacob, 2018). Meeting the demand for housing units as of 2023, which stands at approximately 3,10,000 units using the current materials, would result in emissions of around 3.64 million tonnes of CO_2e. Meeting the housing demand for 2031, which stands at 430,000 dwelling units using current materials, would cause an additional 5.01 million tonnes of CO_2e emissions.

Through several structured initiatives, the state of Odisha has made significant progress in tackling the issue of affordable housing. Affordable housing delivery is driven in the State through the "**Pradhan Mantri Awas Yojana**," a flagship program of the central government to cater to housing demand. This scheme operates in tandem with the state government's efforts to provide financial assistance to vulnerable sections of society for constructing houses. Odisha's "**Jaga Mission**" is a transformative initiative aimed at providing safe and liveable habitats for slum dwellers. Launched in 2018, the mission focuses on urban land tenure and property rights, aiming to upgrade slums and informal settlements into resilient and inclusive neighbourhoods.

The "**Odisha Affordable Housing Policy**" promotes partnerships between public and private entities to create affordable housing projects. This policy ensures that urbanisation benefits all citizens, including those from low-income backgrounds. Other significant initiatives for housing include the "**Mo Ghara Scheme**" to provide credit-linked fiscal support to beneficiaries who face fund shortages to complete or upgrade their homes; the "**Nirman Shramik Pucca Ghar Yojana**", which is tailored

Figure 2: Projection of CO_2 emissions based on different construction materials[3]



to address the housing needs of construction workers, and the "**Biju Pucca Ghar Yojana**", which aims to provide pucca (permanent) houses to families living in kutcha (temporary) houses in rural areas. By focusing on rural and urban contexts and targeting various marginalised groups, these schemes significantly improve the overall quality of life and foster sustainable development in the state. It is evident, however, that the provisioning for housing and policies around the same do not adequately consider the environmental impacts of the construction activity involved.

As per an IFC report from 2017, green building construction is mostly prevalent in and around major metropolises like New Delhi, Mumbai, Bangalore, and Chennai. Tier 2 cities like Bhubaneswar have yet to mainstream the use of green technologies and sustainable materials in residential construction. While other states have incorporated instruments like tax reduction, stamp duty reduction, and additional FAR for certified green buildings, Odisha still lacks lucrative incentives to developers, limiting the interest to avail of green certification. The stakeholders are unaware of the economic and environmental benefits it provides in the long run. Further, builders are also not receptive to the idea of incorporating sustainable building materials and practices due to the perception that such practices increase construction costs, thus discouraging the uptake of such materials. Overall, there is a severe lack of market mechanisms that enable the adoption of green building practices and sustainable materials, thus limiting their adoption in construction.


A stack of fly ash bricks

3 Projections based on data provided in CDP-BDPA, 2031 https://www.orissalinks.com/bigfiles/Draft%20Proposal_CDP%20BDPA-2008/Chapters/Chap7-Housing%208%20Slum.pdf

Circularity Approaches for the Built Environment

With an array of strategies, frameworks, and guidelines, India has showcased its commitment to greener and sustainable future.

Strategies, Frameworks, and Policies Promoting Resource and Energy Efficiency

Strategy on Resource Efficiency – Introduced by NITI Ayog in 2017, this was aimed at optimising resource use in India's booming construction and mobility sectors, further expanding to diverse resources for sustainable development.

India-EU Resource Efficiency and Circular Economy Partnership – The partnership was established in 2017, uniting stakeholders from both regions in a drive for sustainable economic growth and environmental preservation.

Draft National Resource Efficiency Policy (NREP) – MoEFCC launched the draft NREP in 2019, envisioning a future marked by eco-friendly economic progress, emphasising circular approaches and waste reduction in sectors like automotive, plastics, and steel.

C&D Waste Management Rules – notified in 2016, to prevent mismanagement of construction debris.

MSME Policy - echoed these sentiments, promoting energy efficiency, waste management and energy conservation by enabling support to MSME stakeholders

G20 Delhi Declaration - Promotion of sustainable lifestyles (LiFE) for a global net zero, emphasizing circular economy and launching a Resource Efficiency and Circular Economy Coalition

Energy Conservation Building Code and Eco Niwas Samhita - The BEE, under the Ministry of Power, introduced ECBC in 2007, setting energy efficiency standards for commercial buildings. ENS sets standards for residential buildings, promoting energy efficiency.

To promote the use of responsible building materials, it will be essential to address demand and supply side bottlenecks in the sectoral value chain. For Odisha to develop sustainable supply chains for building materials, it must tap into the wealth of secondary resources available and likely to be generated in the state. Odisha generates significant construction and demolition waste and other types of waste annually. The city of Bhubaneswar alone is estimated to generate around 200-250 metric tonnes per day of construction and demolition waste (GIZ, 2022). The different types of industrial wastes generated in Odisha every year include over 41 million tonnes of fly ash, 6 million tonnes of phospho-gypsum, 8 million tonnes of red mud, 15 million tonnes of dolochar and dust, and 26 million tonnes of slag. Despite extensive research and development by industries and academic institutions on their potential utilisation, these materials are currently utilised in very little quantity out of the total amount generated.

The utilisation of innovative materials derived from these available secondary resources in Odisha for future construction can aid the state in significantly reducing emissions from the building and construction sector. Such alternatives have been developed and tested by various agencies. Sintered fly ash aggregates, with up to 90-95% fly ash content, are an apt replacement for coarse aggregates that can help reduce associated emissions by 30-40% and eliminate the need for stone quarrying. The traditional clay brick can be replaced with fly ash bricks and AAC blocks composed of 60% fly ash, which will help reduce emissions from bricks by 70-80%. Geopolymers, a combination of Ground Granulated Blast-furnace Slag (GGBS) and Portland cement, is an alternative for ready-mix concrete that can reduce emissions by 40-55%. Limestone Calcined Clay Cement, or LC^3, is a replacement for conventional cement with a composition of 50% clinker, 30% limestone, 5% gypsum, and 15% calcined clay, which can reduce emissions by 30-40% during the production process.

It is thus clear that, if managed effectively, this waste has immense potential to be repurposed and utilised in future construction projects, reducing the burden on landfills and conserving natural resources. By implementing sustainable practices and incorporating recycled materials into new construction, Odisha can contribute to environmental conservation and develop a circular economy in the construction sector.

Recommendations

Odisha has shown tremendous initiative and success in transitioning from burnt clay bricks to fly ash bricks through a combination of policy and market initiatives and, therefore has a precedent to learn from. Similar zeal is needed to transform the built environment by creating an enabling ecosystem for new, responsible materials and technologies.

The following overarching recommendations shall be used as guiding principles for designing the roadmap with specific actions across the three thrust areas. The cross-cutting recommendations will be foundational priorities and key enablers to ensure the successful implementation of the proposed roadmap.

Policy Frameworks

- **Visions and Targets** – It is essential to establish a shared vision towards achieving decarbonisation goals and establishing circular material economies for the built environment. Such a vision must consider the various constraints and opportunities at the state level and institute discrete, measurable targets towards achieving the same.

- **Policy Packages and Frameworks** – Individual, siloed policies will not be sufficient to drive industry transitions. The need is to design cross-sectoral policy packages based on key priorities for implementation. Such policy packages must build in adaptive planning capacities and put in place updatable frameworks to respond to the dynamically changing realities of the sector.

- **Regulations, Codes and Standards** - Combinations of carrot and stick mechanisms are needed to regulate the production and consumption of conventional materials. Appropriate regulations can help eliminate environmentally irresponsible materials from markets. Formulation of relevant quality standards and integration of new materials and technologies into state-level building codes and guidelines will be crucial to enable their effective utilisation.

- **Sustainable Public Procurement** is a key lever for transformative action and can help stimulate demand-side shifts and facilitate the influx of alternative materials and technologies into the market. Building environmental performance criteria and minimum energy requirements into public procurement processes, including tender documents and BOQs, can provide a boost to the demand for alternative materials.

- **Adoption of green building certification systems** – Adopting and promoting mandatory or voluntary green building certification systems such as Eco Niwas Samhita, IGBC, GRIHA, EDGE, LEED, etc. is critical to align building design and planning with sustainable design principles. This can also assist in securing finance for such development.

Markets and Finance

- **Fiscal and Non-Fiscal Incentives** will be necessary to nudge the market towards sustainable materials and meet the high upfront costs associated with the transition. Fiscal incentives may include subsidies, tax rebates, preferential lending, etc. In contrast, non-fiscal measures may include expedited approvals, fee reductions, transferable development rights and other mechanisms to attract developers and architects towards alternative building systems.

- **Viable Business Models** – Production and consistent supply of alternative materials will be hinged on profitable business models that are sustained by regular demand. Innovative business models and delivery systems will need to be designed to ensure that available technologies can be mainstreamed into the markets while ensuring financial feasibility and growth of the local economy

- **Awareness Building and Changing Consumer Preferences** – There is a need to generate awareness among developers and buyers regarding the benefits of 'going green'. Extensive communication is needed to establish the notion of 'buildings as carbon' and of green buildings being profitable in the long term.

Materials and Technology

- **Research and Development Ecosystem** – A strengthened ecosystem is required for innovation in material technologies and providing support for their incubation and demonstration. Furthermore, it would be essential to adopt a forward-looking approach to identify and develop materials of the future, especially bio-based materials and low-carbon, circular technologies.

- **Pilot Demonstrations** – Demonstration cases that can help generate environmental performance data and validate the feasibility of solutions are crucial to bring alternative technologies into the mainstream. These can then be used as best practices for further dissemination and building confidence among users.

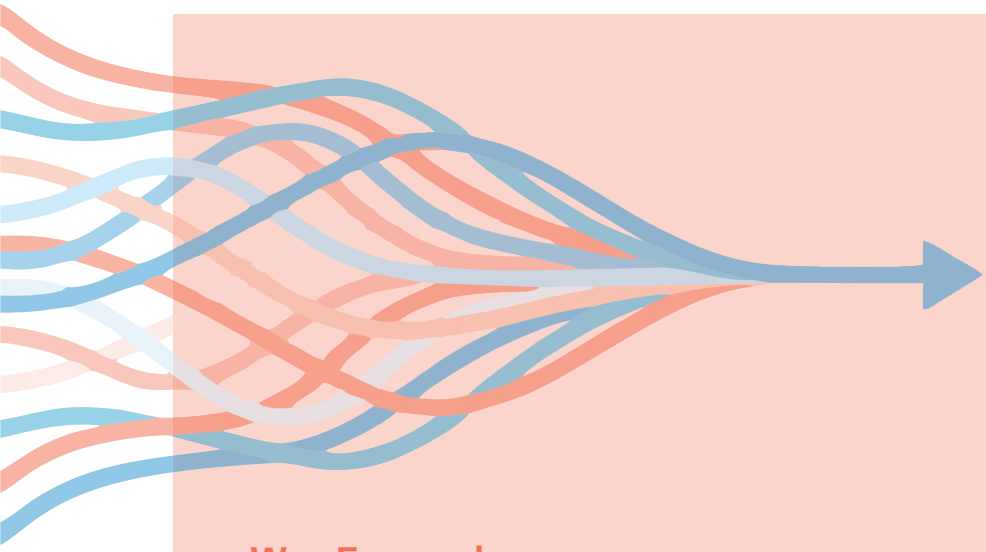
- **Rating Tools, Labelling, and Data Frameworks** – AAccess to detailed, high-quality information on the carbon and resource footprint of materials will be vital to measure and track the performance of alternative materials. This must be guided by a life cycle approach to ensure that decarbonisation and circularity benefits are incorporated in a responsible manner. The end of life of buildings will be important to look at using tools such as Material Passports.

Cross-cutting

- **Multi-stakeholder engagement** - Institutional mechanisms must be established to ensure coordination and coherence across sectoral priorities and bring together various stakeholders for collaborative action. The participation of stakeholders across the buildings and construction value chain will be crucial to derive synergistic benefits and effect change.

- **Capacity Building** – Extensive training and awareness building is required for stakeholders across all three thrust areas across the public and private sectors. This includes policymakers, officials from various government line departments, professionals from the architecture, engineering, construction, and design fraternity, and developers and financiers. Sharing best practices from around the world and specific examples from other states will be instrumental in designing innovative yet practicable implementation pathways for market transformation.

- **Innovative financial instruments** will be powerful enablers for large-scale action at both state and city levels and fill gaps in capital availability for green buildings. This will necessitate setting up institutional financial mechanisms to support industries in producing sustainable building materials and enable developers to incorporate these new materials. These may include instruments such as green or municipal bonds, carbon market revenues, funds from multilateral financing institutions, green housing finance, etc.



Way Forward

The baseline assessment carried out in Odisha provides a comprehensive overview of the affordable housing sector and the various gaps and barriers in mainstreaming the use of sustainable building materials in construction practices. At the same time, there are emerging priorities at the state level that present opportunities to align policy mandates with circularity and decarbonisation concerns to support the government in meeting its development targets as well as contribute to the NDCs and SDGs.

The findings from the assessment will be instrumental in crafting the way forward for the state to initiate coordinated action towards establishing its ambitions and developing actionable strategies to achieve the same. A series of steps and activities are outlined in this report towards this, including:

- **Roadmap development** based on the findings and recommendations of this baseline assessment report, a consultative process will be carried out to establish clear actionable pathways for the state to achieve a shared vision for the sector based on scientifically established targets and goals.
- **Institutional Coordination and Technical support** through working groups composed of key local stakeholders across three thrust areas – policy frameworks, market and finance, and materials and technology.
- **Demonstration of solutions** for potential reduction in material and carbon footprints through pilot projects to inform new policy frameworks, business models, standards and regulations, incentive models, and procurement strategies.
- **Capacity building** of various stakeholders across the buildings and construction sector value chain based on a detailed capacity needs assessment in the state.
- **Dissemination of knowledge** developed through the project to raise awareness and highlight the potential benefits of the adopted approach.

Construction workers pour concrete into a reinforced precast slab

1. Introduction

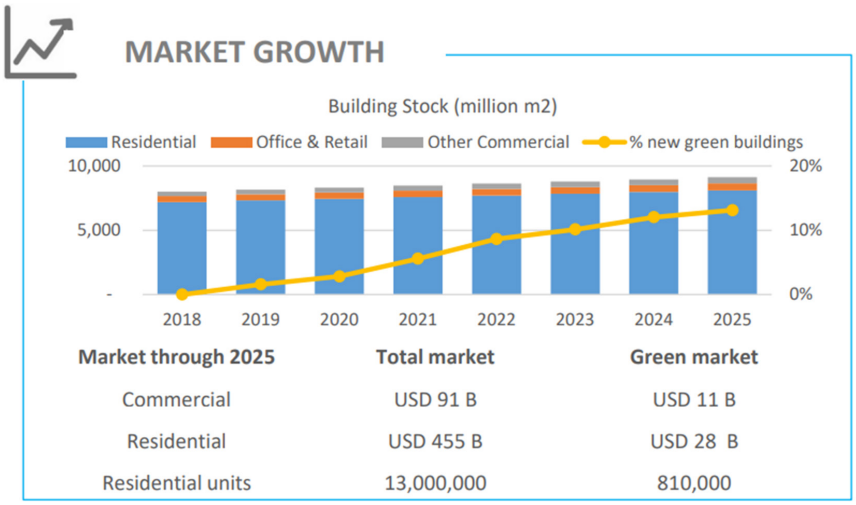
1.1 Background

The building and construction sector is one of the significant sources of greenhouse gas emissions. In 2019, the sector accounted for 38% of total global energy-related emissions, with building materials accounting for over 10% of indirect emissions (GlobalABC, 2020). The increase in economic growth in developing countries also calls for the demand for a new built environment. Expanding the built environment would result in higher material production and consumption, operational energy use, and embodied energy emissions. The emissions from the sector would need to decrease by almost 98 percent from their level of 38% in 2020 to align with the goal of achieving net zero carbon emissions by 2050. With the acknowledgment of governments across the globe about the importance played by buildings in decarbonisation, around 80% of the countries recognise the sector in their Nationally Determined Contributions (NDCs) (GlobalABC, 2022).

Rapid urbanisation and rising population drive demand for additional urban infrastructure and housing. India witnesses rapid urbanisation due to increasing population, rural-urban push or migration, and reclassification of rural to urban areas. With the expanding population, urbanisation, and lack of infrastructure, it is estimated that 70% of the buildings that would cater to social needs are yet to be built in India (IFC, 2017). Building stock in India is estimated to increase by 5.7 billion square metres by 2030, 21.5 billion square metres by 2040, and 45 billion square metres by 2060 (Sujit, 2021). Over 22% of all carbon emissions in India are attributed to the construction industry, of which 40% accounts for embodied energy and 60% for operational energy. With standards and codes like Eco Niwas Samhita (ENS), Energy Conservation Building Code (ECBC), and Standards and Labelling Programmes (S&L), current policies in India are focused on operational energy with little emphasis on embodied carbon emission (AEEE, 2022).

Figure 3: Estimated building stock growth in India

Source: IFC, 2017



Given the enormous development necessary to meet India's demand for affordable housing, building materials will play a crucial role in determining future natural resource production and consumption trends. India can use circular economy principles and decarbonisation strategies to develop affordable homes to meet sustainability goals and achieve high environmental performance in the built environment. This approach can simultaneously help generate livelihoods and new economic opportunities through innovative business models and productive utilisation of secondary resources from industrial, agricultural, construction, and demolition waste.

1.2 About the Project

The three-year project, 'Transforming the Built Environment through Sustainable Materials,' aims to create a market for sustainable building and construction materials. The project seeks to address the gaps in the construction sector value chain to assist in transforming the supply and demand side bottlenecks and transition to low-carbon pathways for the sector by developing a sustainable building materials market in Indian states. This approach is aligned with the draft national-level roadmap currently under development by the Bureau of Energy Efficiency for mainstreaming energy efficiency in residential buildings. The project's various outputs and activities are projected to improve the climate ambition of NDC targets in the sector by 2025, particularly by incorporating actions and targets to reduce embodied carbon. Establishing a responsible building material acquisition framework will also promote building circularity. The expected outcomes of the project are as follows;

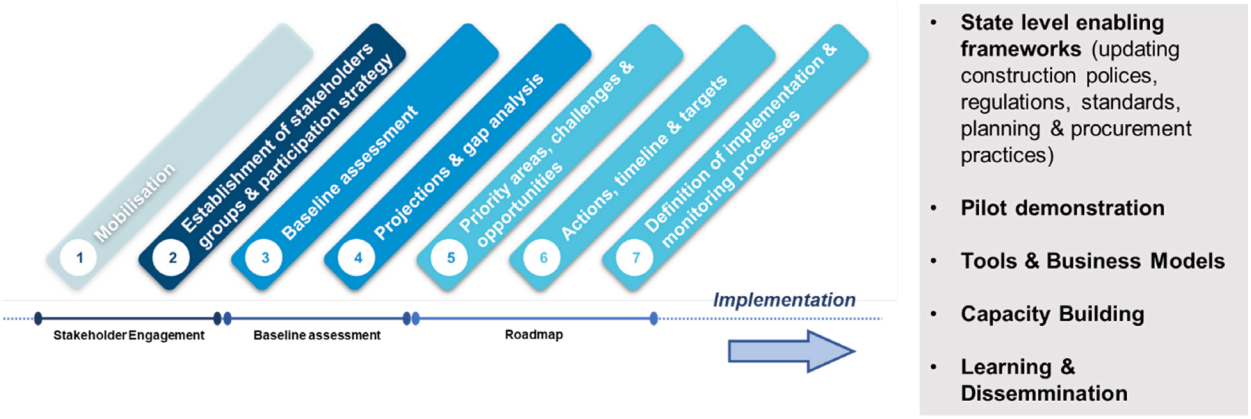
- Demonstration of potential reduction of carbon and material footprints in affordable housing initiatives through actual on-ground pilot projects in Odisha and Maharashtra.
- State-level roadmap and enabling frameworks (updating construction policies, regulations, standards, planning, and procurement practices) to mainstream resource efficiency and environmental performance for building and construction materials.
- Application of innovative, cost-effective tools and business models for applying low carbon resource efficient building materials and circularity practices in the buildings and construction sector on a municipal/city level.
- Learning and information – capacity building and knowledge development on establishing sustainable materials markets for the buildings and construction sector, dissemination in national and global fora.

The project will be undertaken in four countries: Ghana, Senegal, Bangladesh, and India. In India, the project aims to develop a state-level roadmap for decarbonising the building and construction sector and undertake other activities to facilitate an enabling ecosystem for the systemic transformation of the sustainable building materials market for affordable housing in selected states, Odisha and Maharashtra. In India, the project will focus on making sustainable materials and building construction technology more accessible to the affordable housing sector. The project's scope is limited to affordable housing due to the varying complexities involved in the Indian built-environment sector, government priorities, and the high proportion of affordable housing in the construction sector. The project aims to transform the affordable housing sector through sustainable building materials, covering policy and technical aspects, markets, financial systems, skills, and local dynamics. The roadmap will work within the system boundary of the State's affordable housing development as per the prevalent typologies in the target city and State. The proposed roadmaps will be developed using the methodology and frameworks created by GlobalABC.

1.3 Project Approach

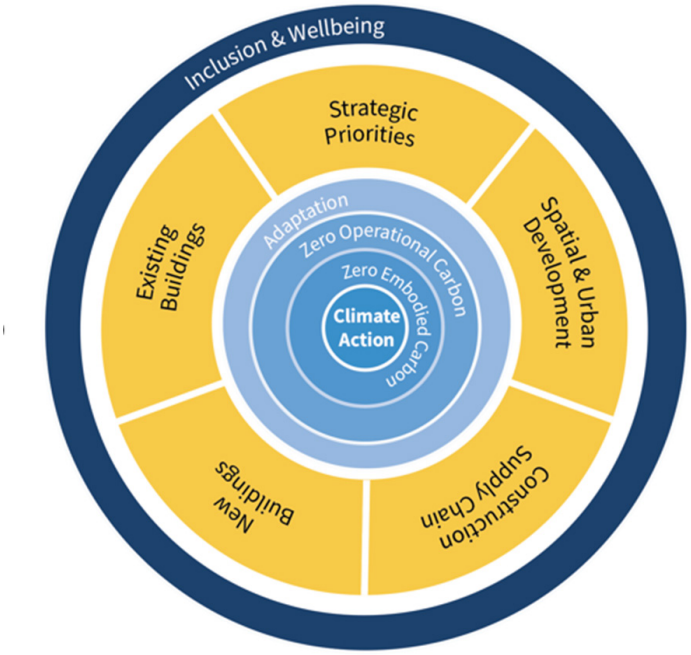
The project will follow the 3-stage GlobalABC methodology. Founded at COP21, hosted by the United Nations Environment Programme and with 280 members, including 38 countries, the Global Alliance for Buildings and Construction (GlobalABC) is the leading global platform for all buildings stakeholders committed to a shared vision: A zero-emission, efficient and resilient buildings and construction sector. The first stage of the GlobalABC methodology, stakeholder engagement, includes mobilisation and establishment of stakeholder groups and participation strategy. The second stage, baseline assessment, includes state baseline assessment, projection, and gap analysis. The third stage of roadmap development includes identifying priority areas, challenges and opportunities, actions timelines and targets, and implementation and monitoring, followed by pilot projects.

Figure 4: GlobalABC methodolgy



The GlobalABC framework for transforming the built environment through sustainable building materials is designed around five action areas: strategic priorities, spatial and urban planning, existing buildings, new buildings, and construction supply chain, intending to enable zero embodied carbon, zero operational carbon, adaptation, and inclusion and well-being. This includes measures on guided preferential procurement, integrated urban planning, supportive policy frameworks coupled with appropriate financing opportunities and reporting systems, and a robust supply chain, which will facilitate the transition towards circularity and sustainable materials. The process relies on a highly collaborative approach to establish a shared vision and tangible goals for the State based on actionable strategies.

Figure 5: GlobalABC framework for transforming built environment through sustainable building materials



This comprehensive report providing baseline assessment on the housing sector of Odisha was meticulously developed through extensive secondary literature review. Major keywords used for the literature review include affordable housing in Odisha, housing stock, housing shortage, and housing demand in Odisha, sustainable materials in affordable housing, local building materials in Odisha, building and housing sector policies and legislations among others. Additionally, information was collated from relevant government bodies at the state level, and state and central government reports on dissemination of affordable housing, SDG frameworks, and financial report among others. This multi-faceted approach ensured a thorough exploration of the topic, resulting in a well-informed report that could guide future practices in the realm of affordable housing in Odisha.

Open space built under JAGA mission where communities gather

1.4 Potential Risks and Mitigation Strategies

The potential risks identified that could affect the implementation of the roadmap and project activities and respective mitigation strategies are listed below.

Potential Risks	Mitigation Strategies
Lack of stakeholder engagement	The project will build strong relationships and engage with market and non-market stakeholders who are influential at the state level concerning the building and construction sector, like IGBC, OSHB, Jaga Mission, and academic institutions in Odisha (XIMB, IITB, KIIT, others). The formal partnership with OSHB will be leveraged to invite support and interest from other relevant stakeholders.
Intended mitigation strategies employ technologies, materials, and processes with negative environmental impacts outside the project's scope.	The project will pay special attention to the value chain and life cycle impacts of the proposed solutions. It shall endeavour to adopt an integrated approach that considers social and environmental impacts, and decision-making will be based on robust data and scientific assessment.
Change in political priorities	The project will endeavour to embed the recommendations in sub-national level policy frameworks. The subnational level recommendations will be aligned to relevant national policy frameworks with broader development goals, ensuring resilience and continuity in implementing the roadmap.
The absence of standardised certification for recommended sustainable materials hinders commercial adoption.	The project will engage with relevant authorities and agencies including the BIS, IGBC, BMTPC, etc from the onset to explore solutions for the adoption of recommended materials. The available building materials at TRL 5-6 will be informed with relevant short-medium-long term recommendations (e.g., driving R&D investments) to bring them to higher TRL.
Potential rising costs associated with the solutions promoted by the project could lead to a lack of implementation and stakeholder resistance to change.	The project will work closely with industries to identify suitable materials for piloting. The programme will focus on affordable and locally adapted solutions and recommend tailored financial mechanisms based on relevant cost benefit analyses. Implementing partners will use participatory approaches to engage relevant stakeholders capable of bringing in fiscal incentives and subsidies for adopting emerging sustainable building materials.
Issues in data availability (e.g., with respect to accurate estimation of the quantity of secondary resources available, exact carbon footprints, etc.) and data transparency	The project will employ the Life Cycle Analysis (LCA) methodology developed by the Center for Advanced Research in Building Science & Energy (CARBSE), which allows for a robust analysis based on different levels of data accuracy and completeness that have been built into the methodology to account for assumed challenges in data collection and reliability. The data projections and analysis will be conducted based on secondary research and global standards. The project will make recommendations on setting up data collection/sharing frameworks to improve data accessibility relevant to the built environment.

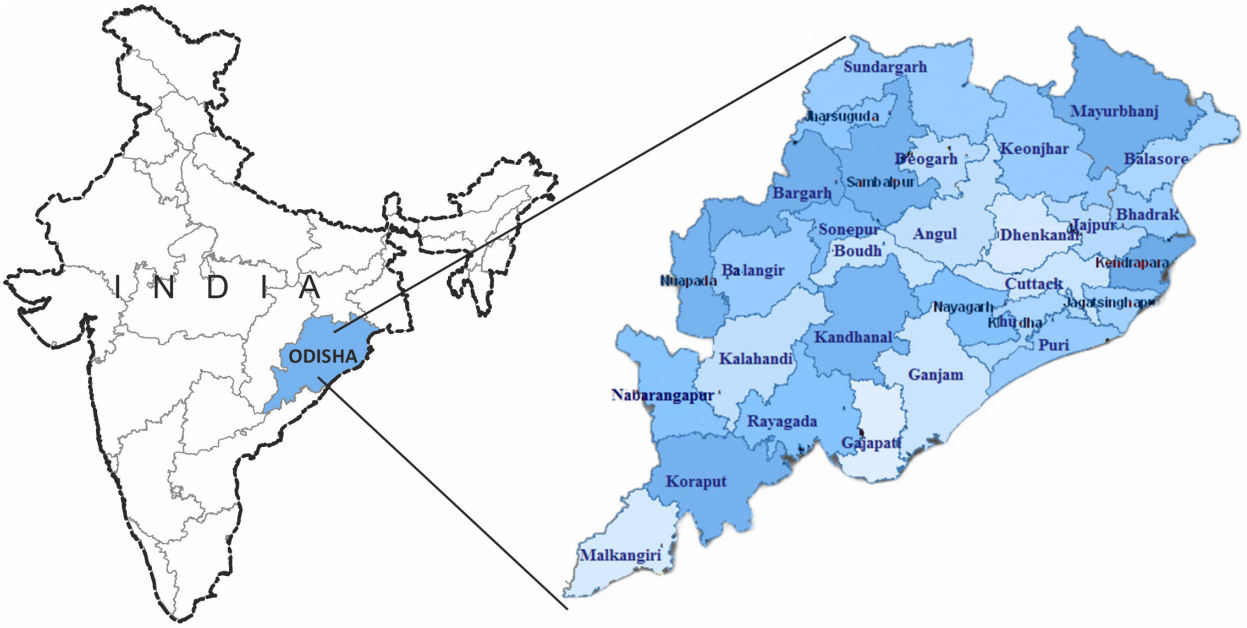
Affordable housing construction in progress

2. Odisha State Overview

2.1 Geography and Climate

Along its 480 km coastline, the eastern Indian State of Odisha boasts a diverse terrain that includes coastal plains, hills, and plateaus. Odisha's vibrant events like the Rath Yatra, well-known temples like the Sun Temple in Konark and the Jagannath Temple in Puri, and traditional dances like the Odissi are just a few instances of the State's rich cultural heritage(Government of Odisha, n.d.).

Figure 6: State outline of Odisha



Basic Physical and Topographical Data

Odisha is the **ninth-largest State** in India, with a total size of around 155,707 square kilometres (60,119 square miles). In Odisha, there are considerable variations in elevation. The interior regions have higher elevations, whereas the coastal regions are often low-lying. The Eastern Ghats' hilly sections have an average elevation of around 900 metres (2,953 feet) above sea level, which is higher than the sea level near the coast. A variety of relief characteristics characterises the geography of Odisha. There are three main regions in the State:

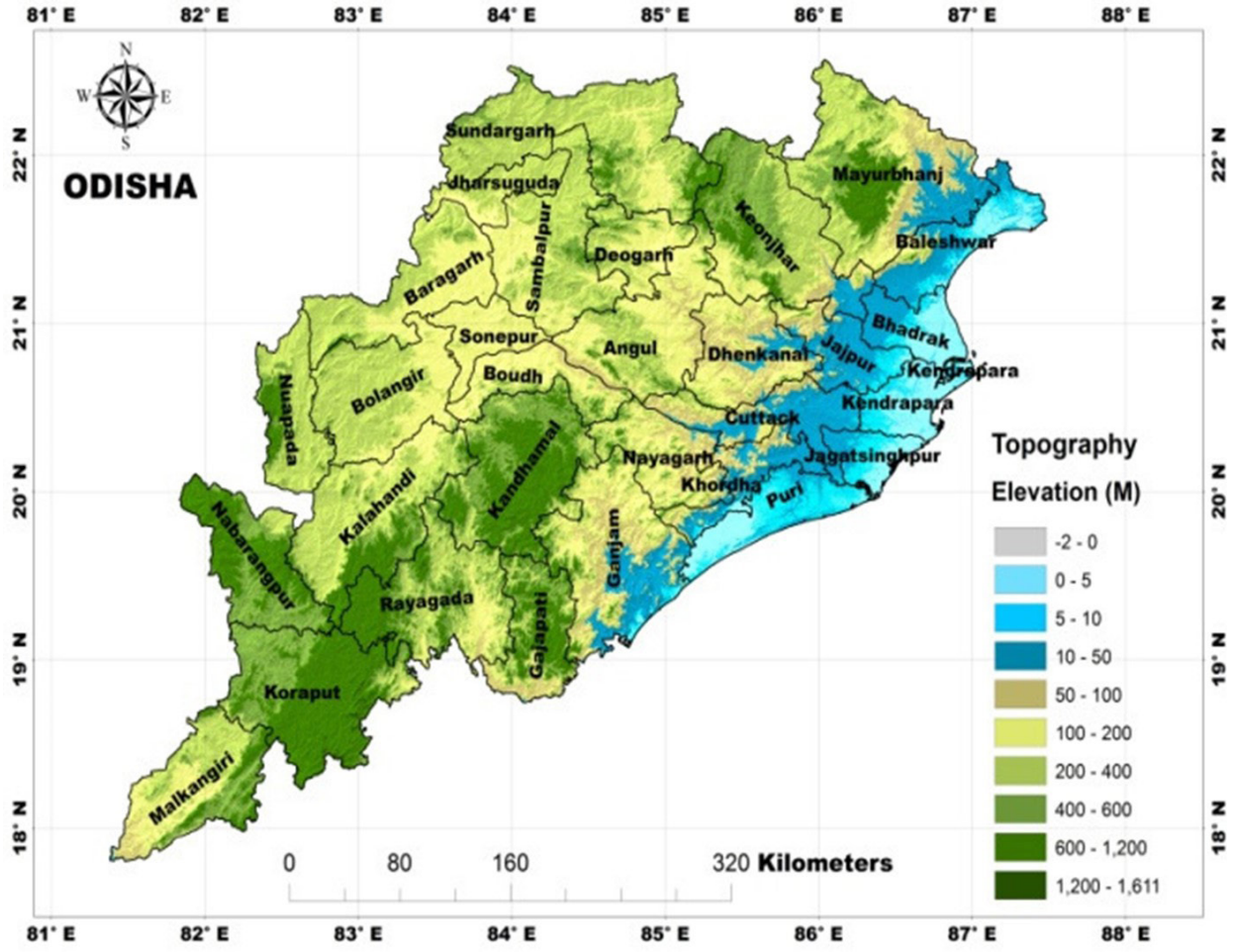
1. **Coastal Plains:** The coastal lowlands extend around 480 km along Odisha's eastern coast. Sandy beaches, estuaries, and lush delta regions—all created by rivers pouring into the Bay of Bengal—define them.

2. **Eastern Ghats:** The State's easternmost, hilly area, which is made up of several plateaus and mountain ranges. Deomali, which lies in the Koraput district and has a height of around 1,672 metres (5,486 feet), is the highest peak in Odisha.

3. **Central Plateau:** Western Odisha comprises the Western Odisha Plateau with districts like Sambalpur, Bolangir, and Koraput, featuring undulating terrain and forests. The northern part is called the North Odisha Plateau, including districts like Mayurbhanj and Balasore, known for fertile plains and the forested uplands(Forest & Environment Department, n.d.).

Figure 7: Topography of Odisha

Source: Comparative Study of Monsoon Rainfall Variability over India and the Odisha State, MDPI Journal

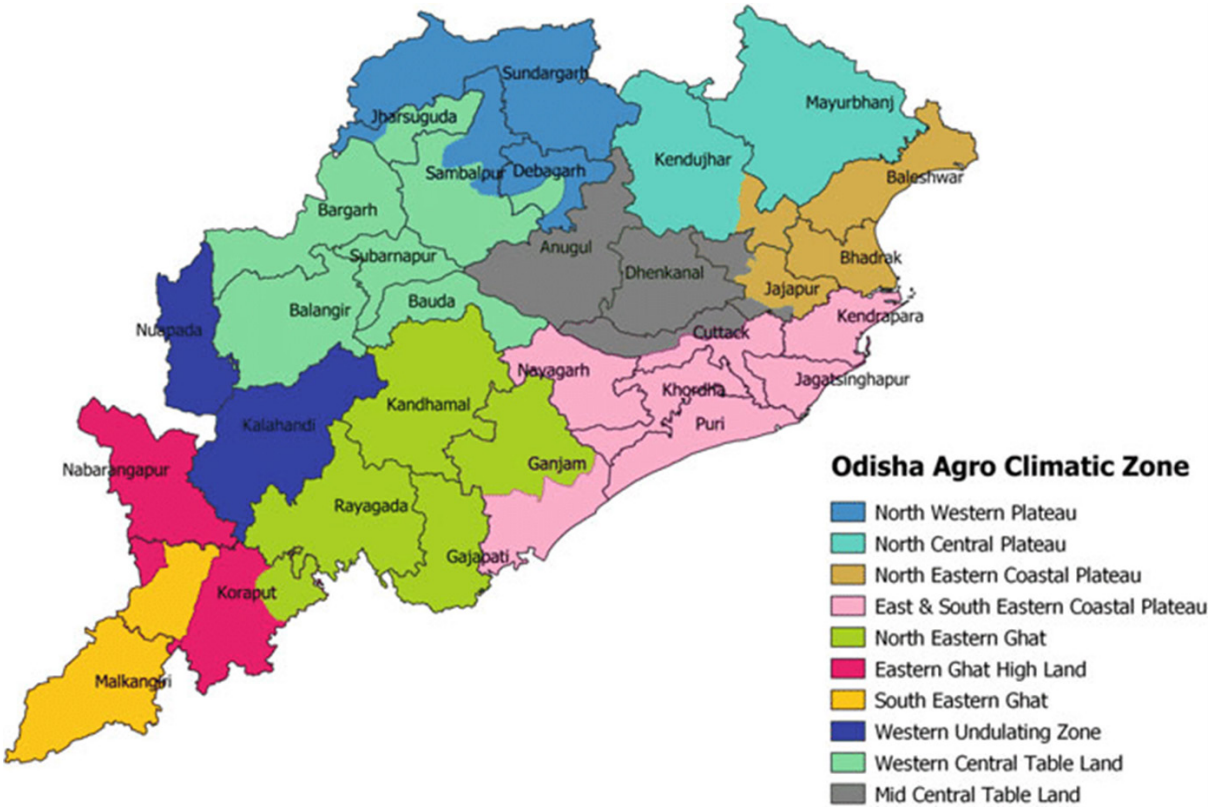


2.1.2 Climatic Zones

Odisha experiences a tropical climate with high temperatures, humidity, and medium to high precipitation. According to Koppen's climate classification, most of Odisha has a tropical Savannah climate (AW – Tropical wet and dry climate). The southwest monsoon typically arrives between June 5 and June 10, covering the entire State by July 1st and leaving by October 15th. Due to insufficient winter precipitation, Odisha falls into Thornthwaite's "Sub-humid" category. The State is divided into eleven agro-climatic zones based on climate type, with an average annual rainfall of 1451.2 mm. Cyclones, droughts, and floods of varying intensity occur almost every year.

Figure 8: Agro climatic zones of Odisha

Source: Drivers of Agricultural Growth in Odisha, Revitalizing Indian Agriculture and Boosting Farmer Incomes



2.2 Political Context and Governance

The current Odisha Legislative Assembly is unicameral, with 147 Members of the Legislative Assembly (MLA) serving a term of 5 years. The State is represented at the national level by 21 members in the Lok Sabha and 10 members in the Rajya Sabha. The state government comprises various agencies, including Agriculture, Education, Health and Family Welfare, Rural Development, Water Resources, and Women and Child Development. Odisha is divided into 30 districts, each led by a District Collector, while the Chief Secretary serves as the State's administrative head. The State has a three-tiered Panchayati Raj system comprising Gram Panchayat, Panchayat Samiti, and Zilla Parishad, overseeing rural areas.

2.2.1 Decentralised System of Governance in India

1India follows a federal system of governance. Powers and responsibilities are distributed across three tiers: the Union or the Central Government, the State, and the Local Governments. The division of responsibilities across these three tiers is laid out in the Seventh Schedule of Article 246 of the Indian Constitution. The subject of housing is not specifically mentioned in the Seventh Schedule.

The 74th Constitutional Amendment Act 1992 provided for the setting up of an administrative structure that would allow the devolution of powers. The Act envisages three types of Municipalities: Municipal Corporations for large cities, Municipal Councils for smaller cities and towns, and Nagar Panchayats for areas in transition from 'rural' to 'urban'. Accordingly, the state governments have re-categorised different areas by notifying the criteria for the classification of municipal bodies, and these bodies have been accorded constitutional status for governance. The Twelfth Schedule of the Constitution lists the various functions of urban local bodies (ULBs). The provision for housing for low-income groups falls under the discretionary functions enlisted in the Twelfth Schedule (The Constitution (Seventy-Fourth Amendment) Act, 1992| National Portal of India, n.d.).

2.2.2 Formal Governing Measures through Local Authorities and other Development Agencies

a. Role of the Central Government in Urban Governance

The **Ministry of Housing and Urban Affairs** is the apex authority of the Government of India at the national level to formulate policies, sponsor and support programmes, coordinate the activities of various Central Ministries, State Governments, and other nodal authorities, and monitor the programmes concerning all the issues of urban employment, poverty, and housing in the country (The Ministry of Housing and Urban Affairs Website, n.d.).

The national policy issues are decided by the Govt. of India, which also allocates resources to the State Governments through various Centrally Sponsored schemes, provides finances through national financial institutions, and supports various external assistance programmes for urban development in the country as a whole. The indirect effect of the fiscal, economic, and industrial location decisions of the Govt. of India exercises a far more dominant influence on the pattern of urbanisation and real estate investment in the country (Ibid).

The organisations relevant to the building and construction sector are listed in the table 20;

Table 20: List of government stakeholders that influence policy frameworks, materials, and carbon footprints and markets and finance

Source: Stakeholder Analysis Report, Development Alternatives, 2023

S No.	Sector	Stakeholder Category	Name of the Organisation/person
Government Stakeholders - Policy Frameworks			
1	Public Sector	Departments, authorities, and agencies	Ministry of Housing and Urban Affairs, India
2	Public Sector	Departments, authorities, and agencies	National Institute of Urban Affairs, India
3	Public Sector	Departments, authorities, and agencies	Niti Ayog, India
4	Public Sector	Departments, authorities, and agencies	Smart Cities Mission, India
5	Public Sector	Departments, authorities, and agencies	Ministry of Environment Forest and Climate Change, India
6	Public Sector	Departments, authorities, and agencies	Bhubaneswar Development Authority
7	Public Sector	Departments, authorities, and agencies	Bhubaneswar Municipal Corporation
8	Public Sector	Departments, authorities, and agencies	Housing and Urban Development Department, Odisha
9	Public Sector	Departments, authorities, and agencies	Urban Local Bodies, Odisha
10	Public Sector	Departments, authorities, and agencies	JAGA Mission
11	Public Sector	Departments, authorities, and agencies	Dept. of Environment and Climate Change, Odisha
12	Public Sector	Departments, authorities, and agencies	Bureau of Energy Efficiency, India
13	Public Sector	Departments, authorities, and agencies	Energy Conservation Building Code, India
14	Public Sector	Departments, authorities, and agencies	Department of Energy, Odisha
15	Public Sector	Departments, authorities, and agencies	Odisha State Housing Board
16	Public Sector	Departments, authorities, and agencies	CITIIS - NIUA
17	Public Sector	Departments, authorities, and agencies	Odisha Urban Housing Mission
18	Public Sector	Departments, authorities, and agencies	Bhubaneswar Smart City Limited
19	Public Sector	Departments, authorities, and agencies	Odisha State Pollution Control Board

S No.	Sector	Stakeholder Category	Name of the Organisation/person
Government Stakeholders - Materials and Carbon Footprint			
1	Public Sector	Departments, authorities, and agencies	Building Materials and Technology Promotion Council, India
2	Public Sector	Departments, authorities, and agencies	Bureau of Indian Standards
3	Public Sector	Departments, authorities, and agencies	Odisha Renewable Energy Development Agency
4	Public Sector	Departments, authorities, and agencies	National Council for Cement and Building Materials, India
5	Public Sector	Departments, authorities, and agencies	Industries Department, Odisha
6	Public Sector	Departments, authorities, and agencies	Odisha Bamboo Development Agency
Government Stakeholders - Markets and Finance			
1	Public Sector	Public companies and banks	Odisha Industrial Infrastructure Development Corporation
2	Public Sector	Banks, lenders, funds	National Housing Bank
3	Public Sector	Public companies and banks	Housing and Urban Development Corporation, India
4	Public Sector	Departments, authorities, and agencies	Government e-Marketplace
5	Public Sector	Departments, authorities, and agencies	Odisha Urban Infrastructure Development Fund

b. Odisha's Urban Governance Structure and Housing Sector

The 1970s and 1980s marked the emergence of housing and land market involvement by institutions like the Housing and Urban Development Department, Development Authorities, State Housing Board, Urban Local Bodies, Housing and Urban Development Corporation, and State Urban Development Agency. These entities aimed to alleviate housing shortages and enhance urban development.

The state's focal point of urban governance is the state government, operating through the Housing and Urban Development Department (HUDD). The pivotal institution within the state's urban governance framework is the HUDD, which carries out its responsibilities through three directorates and various specialised organisations. Notably, the HUDD had not been considered a significant department until recently. This is evident from the budgetary allocation of a mere Rs. 326.02 crore for the department in 2001-02. However, a substantial change occurred in 2011-12, when the allocation surged to Rs. 1592 crore, making an almost fivefold increase, according to the Annual Activities Report, Housing and Urban Development Department, 2012 (Bhide, 2015).

The Bhubaneswar Municipal Corporation (BMC) operates under the Odisha Municipal Corporation Act, 2002. The Housing and Urban Development Department (HUDD) guides various state departments and parastatal agencies, forming the city's governance framework. Notable entities include:

- Bhubaneswar Development Authority (BDA): Plans, zoning, and housing development
- Public Health Engineering Organisation (PHEO): Water supply, sewerage, sanitation
- Works Department (R&D Division): Roads, bridges
- Odisha Water Supply and Sewerage Board (OWSSB): Water, sanitation schemes
- Water Resources Department (WRD): Major stormwater drains
- General Administration Department (GAD): Land management
- Directorate of Town Planning (DTP): Urban planning advisory

c. Evolution of Bhubaneswar's Housing Landscape

Historically, public institutions like the State Housing Board and the Bhubaneswar Development Authority (BDA) played a pivotal role in Bhubaneswar's housing landscape. However, the private market gained prominence in the 2000s, sidelining public housing agencies. This transition highlighted inadequate housing efforts for the Economically Weaker Sections (EWS) and the urban poor. Challenges like flawed beneficiary selection led to the misappropriation of EWS units.

Economic growth spiked land and housing prices, driving public agencies to the periphery. Private developers outside the state entered the market while public housing projects dwindled. The rise in rural to urban migration further compounded the issue of slums in the city.

d. Rise of Slums and Legislative Response

Slum populations grew, with the 1999 super-cyclone significantly contributing. Post-cyclone, the BMC identified slums on government and encroached land. By 2008, the city hosted 377 slums. OSHB traditionally handled service provision for slums. The Odisha Municipalities Act (2003) transformed the response to slums, ensuring services, entitlements, and integration (USAID, 2012 in Bhide, 2015).

e. Shift in Housing Dynamics

The sub-mission on Basic Services to Urban Poor (BSUP), under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), reshaped the housing sector. Previously, BDA and OSHB led housing creation, particularly for EWS and LIG. BSUP empowered the BMC, bringing it into direct contact with slum dwellers. NGOs also entered the scene, diversifying housing governance (Anand & Anand, 2021). HUDD oversaw project implementation and still does to this day.

2.3 Socio-Economic Development

Odisha has societal issues in social inequality, migration, poverty, education, healthcare, women's empowerment, and child labour. Governmental activities, the improvement of the healthcare system, the promotion of gender equality, and upliftment projects for marginalised populations are all attempts to solve these problems. However, social conditions remain fluid, necessitating constant monitoring and assistance to promote progress and sustainable growth.

2.3.1 Refugees & IDPs

For the past fifteen years, there haven't been any highly publicised instances of widespread internal displacement or refugee populations in Odisha. It's crucial to keep in mind that circumstances might change and that since then, there might have been fresh developments.

Natural calamities like cyclones and floods that have historically affected Odisha have the potential to cause temporary population relocation. In such cases, the impacted population may seek temporary shelter in camps or relocation facilities until they can safely return home.

2.3.2 Human Development Index (HDI)

According to the 2019 Human Development Index Report published by the United Nations Development Programme (UNDP), Odisha has an HDI score of 0.618. Odisha, which ranks 22nd nationally among the states, does well in terms of per capita income due to its higher economic growth rate. Odisha's HDI ranking has improved over time, but it still highlights several areas requiring work. Efforts have been made to address these problems and improve the State's social and economic indices.

2.3.3 Vulnerable Groups

According to the 2011 Census, the SC and ST population, women and girls, children, and PTGs (Particular Tribal Groups) comprise the vulnerable categories in Odisha. PTGs are of 13 groups, namely Birhor, Bondo, Didayi, Dongria-Khond, Juangs, Kharias, Kutia Kondh, Lanjia Sauras, Lodhas, Mankidias, Paudi Bhuyans, Soura and Chuktia Bhunjia(Ota et al., n.d.). PTGs have a population of 82,808, the population of women and girls is 2,07,62,082, the population of children is 52,73,194,

marginalised castes like SC (Scheduled Caste) have a population of 71,88,463 and ST (Scheduled Tribe) has 95,90,756.

These population suffer several issues, including socio-economic exclusion, gender disparities, limited access to healthcare and education, child labour, discrimination, and social exclusion. Government and non-governmental groups are collaborating to address these issues and promote inclusive and equitable development of these communities.

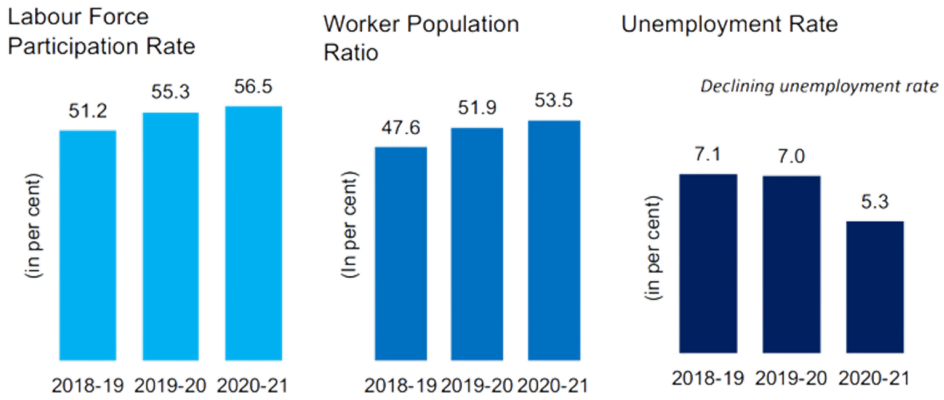
2.3.4 Labour & Employment

According to the Periodic Labour Force Survey, 2020-21, Odisha's LFPR (Labour Force Participation Rate) was 56.5 percent, up from 55.3 percent in 2019-20. In 2020-21, over 53.5 percent of the population aged 15 and up were working, compared to 52.6 percent overall. During 2020-21, the unemployment rate in Odisha was 5.3%, lower than in several high-income states, such as Kerala, which was 10.1%.

Odisha outperforms the rest of India in terms of female labour force participation. In 2020-21, Odisha's female labour force participation rate was 33.2%, compared to 32.5 percent nationally.

Figure 9: Labour force participation, worker population ratio, and unemployment rate – Odisha

Source: Periodic Labour Force Survey (PLFS), NSSO, MoSPI, GoI (multiple rounds - 2018-19, 2019-20, 2020-21)



2.3.5 Per Capita Income

Odisha's current per capita income (2022-23) is INR 150,676, compared to the All-India average of INR 170,620 (current prices). However, in only seven years, the State has decreased the difference between Odisha's per capita income and the national average from 31.6 percent in 2015-16 to 12 percent in 2022-23. Odisha's per capita income CAGR (Compound Annual Growth Rate) from 2011-12 to 2022-23 was 10.9%, compared to India's per capita income CAGR of 9.4%. The pace of growth in Per Capita Income in the State is substantially quicker than the national average, successfully closing the gap (Executive Summary (OES)-2022-23 Final, n.d.).

2.3.6 Employment (Disaggregated by Gender, Formal vs. Informal) of the Construction Sector

1. Formal Employment: Formal employment within the construction sector of Odisha comprises registered and regulated jobs. Construction firms, contractors, and government initiatives often provide these roles. The spectrum of formal employment includes skilled positions (engineers, architects, project managers) and semi-skilled and unskilled labour (masons, carpenters, laborers). These positions typically offer greater job security and access to benefits.

2. Informal Employment: Informal employment pertains to unregistered and less regulated work arrangements. This category involves daily wage laborers, temporary workers, and individuals who lack comprehensive benefits and protections. Informal employment can lack stability and established safeguards.

3. Gender Disaggregation: Historically, the construction sector in Odisha, as in many parts of India, has displayed a gender disparity, with most of the workforce being male. Despite this trend, strides have been made to promote gender equality and increase female involvement in the sector. Women's participation may be more notable in certain specialised roles such as skilled trades, supervision, and administrative positions.

According to Odisha Building and Other Construction Workers Welfare Board, till the FY 2020-2021, a total of 33.53 lakh construction workers registered as beneficiaries under Nirman Shramik Kalyan Yojana, of which 21.75 lakh (65%) are male and 11.77 lakh (35%) are female.

2.3.7 State's Economy

Industries and the Service sector have become the lead sectors and the new driver of growth in Odisha. The primary economic drivers are agriculture, mining (coal, iron ore), industry, and services, with a focus on promoting industrialisation. In 2022-23, Agriculture and Allied Activities contributed 22.5 percent, Industry contributed 41.3 percent, and Services contributed 36.2 percent to GSVA (Gross State Value Added).

The broad mix of industries that make up Odisha's economy includes mining, agriculture, manufacturing, services, and tourism. The State's abundant natural resources significantly boost revenue creation, while agriculture continues to be a critical industry that supports a significant portion of the population. Investments are drawn to manufacturing sectors like steel and aluminium, which promotes the economy's expansion and the creation of jobs. A significant IT hub, Bhubaneswar, supports the services industry. The State's cultural history and natural assets are beneficial to tourism. But issues with poverty and regional inequality continue, calling for more government programmes and regulations for sustainable development (Executive Summary (OES)-2022-23 Final, n.d.).

2.3.8 Poverty Ratio

Odisha is among the top 10 states, with 29.35 percent (pc) of the population living in poverty, according to the NITI Aayog's National Multidimensional Poverty Index (MPI) 2021 study. Unlike earlier years, when poverty was defined as a lack of food, the NITI study covered numerous and concurrent deprivations encountered by households. The MPI is based on three equally weighted dimensions: health, education, and standard of life.

Despite many government projects, social programmes, and handouts, one out of every three people in Odisha is multidimensionally poor.

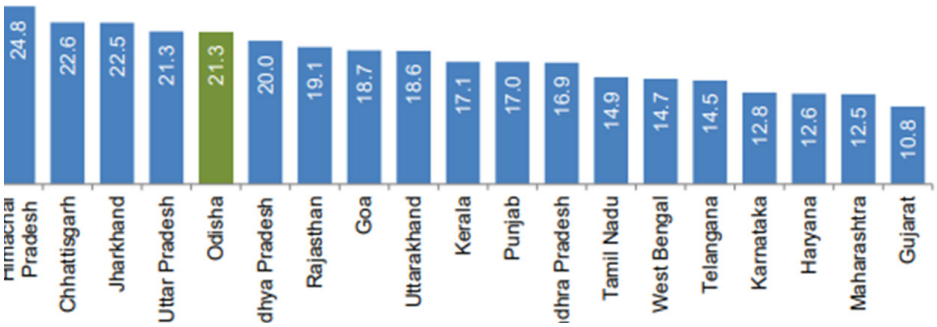
2.3.9 GDP, GDP Growth, GDP Per Capita

During the fiscal year 2022–2023, Odisha's economy had a GDP of almost INR 5.42 lakh crore (USD 65.56 billion), with a growth rate of about 4.20%. The State's GDP per capita, which measures economic production per person, was around 1.2 lakh Indian Rupees.

Odisha is one of the top six spending states in the nation. The State's overall public spending in 2020–21, which includes capital investments and revenue expenditures, was 21.3% of GDP.

Figure 10: Total public expenditure as percent of GSDP in 2020-21

Source: Study of State Budgets, Reserve Bank of India



Affordable housing construction with precast technology

2.3.10 GDP Share of the Construction Sector

The building sector has significantly boosted the GDP of Odisha. With a contribution of approximately 9% to the State's GSDP (Gross State Domestic Product) in the fiscal year 2021–22, the construction sector was one of the State's main drivers of economic growth. The industry has also grown quickly, with a compound annual growth rate (CAGR) of 11.4% from 2015–16 to 2020–21.

A few factors that have fuelled the rise of the construction sector in Odisha include accelerated housing, real estate, and infrastructure development. The state government has been aggressively supporting the industry through several initiatives, including the implementation of the Real Estate (Regulation and Development) Act, 2016, and the creation of a single-window approval system for building projects (Executive Summary (OES)-2022-23 Final, n.d.).

2.3.11 Share of Government Expenditure for Building, Construction, and Infrastructure (Along with Housing Programmes), Including Government Deficit and Gross Debt

A. Odisha Annual Budget Estimates for 2023-24

1. **Housing:** Pradhan Mantri Awaas Yojana (PMAY)-Gramin is worth Rs.5,934 crore. Biju Pucca Ghar has received Rs.487 crore. Under PMAY-Urban, Rs.600 crore is intended for pucca housing for the urban poor (Highlights of Annual Budget Estimates for 2023-24, n.d.).

2. **Urban Development:** For the fiscal year 2023-24, Rs.7,914 crore has been allocated to transform urban Odisha: Rs.600 crore for the Urban Transformation Initiative UNNATI; Rs.100 crore for the Jaga Mission; Rs.414 crore for the wage employment scheme MUKTA (Mukhyamantri Karma Tatpara Abhiyan Yojana); Rs.300 crore for New City Development; and Rs.144 crore for the Urban Water Sector. Odisha is the first State in the country to give Drink from Tap grade water 24 hours a day, seven days a week (Ibid).

3. **Planning & Convergence:** A total of Rs.13,104 crore has been allocated to the Planning and Convergence Department. Infrastructure Development Fund Scheme (IDFS) for KBK (Koraput, Bolangir, and Kalahandi) districts with a Rs.130 crore budget. MLALAD Fund (Member of Legislative Assembly Local Area Development Scheme): Rs.441 crore; Biju KBK Yojana: Rs.250 crore for successful execution of Bijli, Sadak, and Pani projects in KBK districts. The Special Development Programme would get Rs.120 crore. Rs.325 crore for grants to the Western Odisha Development Council (WODC) and Rs.42 crore for the critical Gap Fund, which would address local needs in important sectors at the district level. Rs.200 crore from the Special Problem Fund to undertake minor and vital initiatives in a needy community. Rs.29 crore for the Biju Kandhamala O Gajapati Yojana and Rs.50 crore for the SETU (Socio-Economic Transformation and Upliftment) Scheme (Ibid).

B. Odisha Public Debt Status 2022-2023

The outstanding public debt is the total borrowings after a fiscal year. Other obligations, such as those on public accounts, are not included. The outstanding public debt is anticipated to reach 13.1% of GSDP at the end of 2023-24, up from 12.7% of GSDP in 2022-23. The outstanding state debt has decreased dramatically during 2020-21 (19.2% of GDP). This is due to much higher non-tax revenue (mainly mining revenue) from 2021-22, which has decreased the need for borrowings to cover spending. At the end of 2025-26, outstanding public debt is expected to reach 15.8% of GSDP(Surya, 2023).

2.3.12 Urban Safety Index

Bhubaneswar, the capital city of Odisha, has achieved the **13th rank** in the list of top 20 safe cities globally according to the Global Smart City Performance Index-2017 by Juniper Research. It was evaluated based on crime levels, mortality rates, and the effectiveness of law enforcement services. Additionally, Bhubaneswar secured the 20th spot in three other categories: Mobility (urban transport systems), Health (healthcare service delivery), and Productivity (city policies and technologies aimed at promoting citizen productivity and wealth distribution), as shown in the figure below. Additionally, Bhubaneswar is the only city in the nation to be listed among the top 20.

Figure 11: The top 20 global city performance by index, 2017

Source: https://sambadenglish.com/odisha-capital-ranked-13th-safest-city-in-world/

	Mobility	Health	Safety	Productivity
1	Singapore	Singapore	Singapore	Singapore
2	San Francisco	Seoul	New York	London
3	London	London	Chicago	Chicago
4	New York	Tokyo	Seoul	San Francisco
5	Barcelona	Berlin	Dubai	Berlin
6	Berlin	New York	Tokyo	New York
7	Chicago	San Francisco	London	Barcelona
8	Portland	Melbourne	San Francisco	Melbourne
9	Tokyo	Barcelona	Rio de Janeiro	Seoul
10	Melbourne	Chicago	Nice	Dubai
11	San Diego	Portland	San Diego	San Diego
12	Seoul	Dubai	Melbourne	Nice
13	Nice	Nice	Bhubaneswar	Portland
14	Dubai	San Diego	Barcelona	Tokyo
15	Mexico City	Wuxi	Berlin	Wuxi
16	Wuxi	Mexico City	Portland	Mexico City
17	Rio de Janeiro	Yinchuan	Mexico City	Rio de Janeiro
18	Yinchuan	Hangzhou	Wuxi	Yinchuan
19	Hangzhou	Rio de Janeiro	Yinchuan	Hangzhou
20	Bhubaneswar	Bhubaneswar	Hangzhou	Bhubaneswar

2.4 Climate Risk

2.4.1 Disaster Risk Index

The Finance Commission's Disaster Risk Index (DRI) concept places Odisha at the top of the list of most susceptible states, scoring **90 out of 100**. It was created through a quantitative exercise in which the likelihood of disaster striking different States and the degree of susceptibility were given ratings.

DRI gives a maximum of 15 points to each of the four major hazards that affect different sections of the country - floods, drought, cyclones, and earthquakes - for a total of 60 points. States have been assigned values ranging from 0 to 15 based on the level of probability of a hazard. Furthermore, all states have received an equal score of 10 for lesser local dangers, bringing the total score to 70.

Odisha obtained full grades for floods, drought, and cyclones and five points for earthquakes. The State received full marks in all other categories as well. It also received a full 30 for poverty points, which, when combined with 60 points for DRI, results in a 90 out of 100 score. Odisha's high score stems from its vulnerability to floods, drought, and cyclones, while socio-economic factors, such as poverty, contribute to the index. This underscores the need for tailored disaster preparedness and mitigation strategies to address the State's vulnerabilities.

2.4.2 Recent Ecological Disasters or Climate-related Conflicts

1. **Coastal Plains:** Cyclones frequently occur in Odisha, and they have seriously damaged the State in the past. In May 2019, Cyclone Fani made landfall in Odisha, causing severe infrastructure damage and fatalities.

2. **Floods:** Odisha frequently experiences floods during the monsoon season, causing displacement of people, crop damage, and disruptions in daily life. Recent heavy rainfall 2022 triggered flooding, with Ersama in Jagatsinghpur

District receiving 215 mm of rain in just 24 hours. The average rainfall in the State from the 1st to the 18th of August was 325 mm, slightly below the monthly average of 356 mm, which led to huge floods during the 13th and 14th of August, according to the Odisha State Disaster Management Authority (OSDMA).

3. **Drought:** Odisha faces recurrent droughts, affecting districts like Kendrapara and Sundergarh. In 2015-16, 27 out of 30 districts experienced drought. Heavy reliance on rainfall, unpredictable monsoons, and limited irrigation access intensify agricultureal vulnerability.

4. **Heatwaves:** Odisha faces severe heat waves, with temperatures rising by 0.42 °C in the last 15 years. Vulnerable populations, like the elderly, children, laborers, and those in urban slums, suffer health issues and deaths. Heat waves impact multiple districts, causing lost income opportunities and reduced productivity in various industries, including MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) tasks and mining areas.

5. **Coastal erosion:** The coastal areas of Odisha are susceptible to erosion due to rising sea levels and climate change, affecting communities living along the coastline *(Odisha State Action Plan on Climate Change (Phase-II), 2018*).

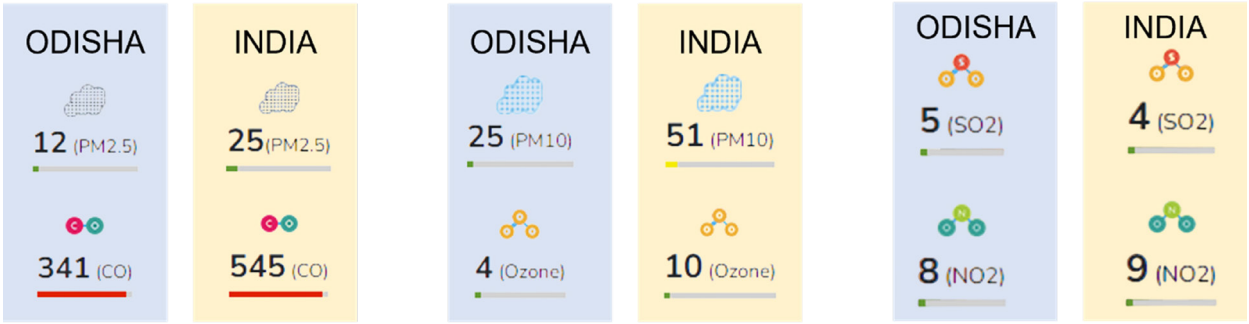
As per OSDMA, over the last 105 years, Odisha has faced disasters from heat waves, cyclones, droughts, and floods for 95 years, becoming more frequent and widespread since 1965.

2.4.3 Air Quality

The State Pollution Control Board (SPCB) enforces the Air Act, 1981, to combat air pollution in the State. The Central Pollution Control Board (CPCB) initiated the National Ambient Air Quality Monitoring network in 1984, with 8 stations established in Odisha in different phases. Currently, Odisha has 15 ambient air quality monitoring stations in cities like Bhubaneswar, Cuttack, Rourkela, Berhampur, Sambalpur, Balasore, Puri, Jharsuguda, Angul, Paradeep, Talcher, Dhenkanal, Kendrapara, Bhadrak, and Jagatsinghpur. These stations measure air pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, O_3, CO, etc.) to assess air quality levels and tackle pollution issues.

Figure 12: Comparison of major pollutants at state and national levels, July 2023

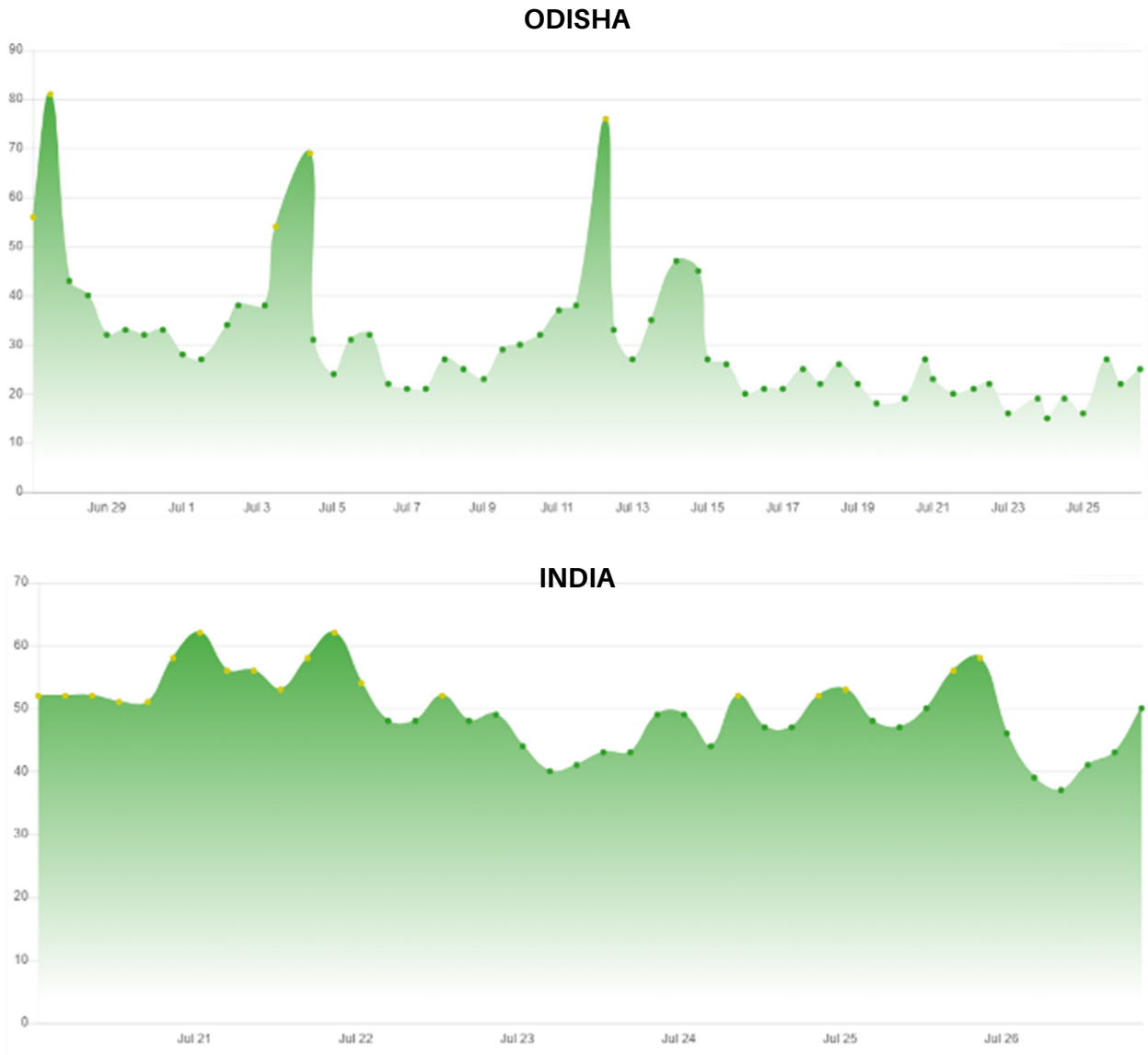
Source: https://www.aqi.in/in/dashboard/india/odisha



The figure above shows that Odisha has effectively controlled pollution, with all major pollutants significantly below national levels and within permissible limits. This indicates a positive environmental trend, potentially leading to better public health and ecological outcomes.

Figure 13: Historic air quality graph of Odisha & India, July 2023

Source: https://www.aqi.in/in/dashboard/india/odisha



The graph shows that the State's AQI consistently falls within the range of 35 to 45. On the other hand, the national average AQI is observed to be higher, ranging between 70 to 80. A lower AQI value indicates better air quality and lower levels of air pollution. The State's air quality index (AQI) is significantly better than the national average.

2.4.4 Resilience and Vulnerability to Climate Change

1. **People displaced internally by natural disasters:** In July 2014, the Mahanadi River delta in southern Odisha was completely submerged by flooding, displacing over a million people. There were large-scale evacuations from low-lying locations.

Table 1: Largest displacement in Odisha, 2014

Source: Displacement by Disasters, No. 1/RN/Ref./February/2016

S.No	Event	Affected Areas	Figure Source(s)	Month	Relative estimate	Absolute estimate
1	Flood	Jajpur, Cuttack, Sambalpur, Bhadrak and Keonjhar districts	International NGO: Oxfam	July	10,73,700	847
2	Cyclone Hudhud	Gajapati, Koraput, Makangiri, and Rayagadathe were the worst affected of the eight districts.	IAG/Sphere India; Advisor to the Andhra Pradesh government and Odisha chief minister	October	6,39,300	504

2. **Population affected due to natural disasters:** In 2020-2022, disasters led to evictions, fatalities, and infrastructure damage, affecting a substantial portion of the population. Below are the figures for the population affected during these years.

Table 2: Population affected by disasters

Source: Annual report on natural calamities 2020-2021 & 2021-22

Population Affected in lakhs		
Disasters	2020-2021	2021-2022
Flood & Heavy Rain	38.90	30.38
Cyclone (AMPHAN in 2021, YAAS & GULAB in 2022)	88.77	45.25

State Specific Disasters

Table 3: Causalities in the State Specific disasters

Source: Annual report on natural calamities 2020-2021 & 2021-22

No. of Causalities in State-Specific Disasters		
Disasters	2020-2021	2021-2022
Lightning	291	281
Drowning	1337	1209
Snake bite	1044	844

3. State disaster risk management: OSDMA has established a commendable track record in disaster response, efficiently handling various disasters. Their focus is to advance beyond reactive measures and foster a culture of prevention and resilience. They aim to achieve this through critical tools like risk assessments, education, coordination, supportive policies, laws, good governance, risk-informed programming, early warning systems, contingency plans, information sharing, and sustainable development.

2.4.5 State's Vulnerability and Readiness to Climate Change

Due to its coastal position and frequent exposure to extreme weather conditions, including cyclones, floods, and droughts, Odisha is extremely sensitive to climate change. Agriculture, water supplies, and biodiversity are all in jeopardy. The State is adopting measures to improve preparation, including disaster management, promoting renewable energy, improving

public knowledge of climate change, and incorporating climate issues into laws and plans incorporated in the Disaster Management Plan 2022-2023. The ability to continuously evaluate and adapt is essential for fostering long-term resilience.

2.4.6 Urban & Rural Heat Islands

The Urban Heat Island (UHI) phenomenon, which causes higher temperatures in urban areas compared to their surrounding rural areas, is influenced by land use, vegetation cover, and population density changes. To ensure sustainable urban development and curb the exacerbation of UHI effects, it is crucial to devise a comprehensive mitigation plan focusing on managing land use and, building sustainable infrastructure with large-scale greening initiatives and mainstreaming sustainable low-carbon building materials.

Odisha sets an example to India in combatting heatwaves through a coordinated approach involving all levels of government (state, district, and blocks), civil society organisations, and industries. The State's heat wave action plan designates specific roles for various government wings, including the Special Relief Commissioner (SRC), Odisha State Disaster Management Authority (OSDMA), and several other departments like Health and Family Welfare, Education, Transport, and more. The OSDMA plays a central role, organising annual meetings of the state Steering Committee to review and update the action plan.

Urban Heat Island in Bhubaneswar

According to research carried out by faculties from the Indian Institute of Technology, Bhubaneswar (Swain & Vinoj, 2017), rapid urbanisation combined with changes in land use patterns has led to about 1.8-degree Celsius warming of Bhubaneswar, compared with surrounding non-urban areas, leading to an urban heat island (UHI) effect.

Table 4: Land Use and Land Cover Changes

Land use & land cover	Absolute area cover (sq.km.)				LULC Changes (%)			
	1991	2001	2011	2021	1991-01	2001-11	2011-21	1991-21
	Area (%)							
Wasteland	1.967	2.046	2.215	1.762	0.05	0.12	-0.31	-0.14
Vegetation	41.275	44.654	36.789	17.809	2.31	-5.37	-12.97	-16.03
Waterbody	25.877	20.563	19.668	32.603	-3.63	-0.61	8.84	4.60
Built up Land	27.590	42.154	57.548	62.601	9.95	10.52	3.45	23.92
Agricultural Land	49.680	36.936	30.169	31.577	-8.71	-4.62	0.96	-12.37

2.5 Environment Impact & Protection

2.5.1 Forest Cover and Land Use Pattern

Forest Cover

Odisha has vast forests. The State lists **58,136 sq. km** (almost 38%) of the total 1,55,707 sq. km of its geographic area as being classified as forest, as indicated in the table below.

Figure 14: Forest Cover & Protected Areas of Odisha

Source: ENVIS Centre of Odisha's State of Environment

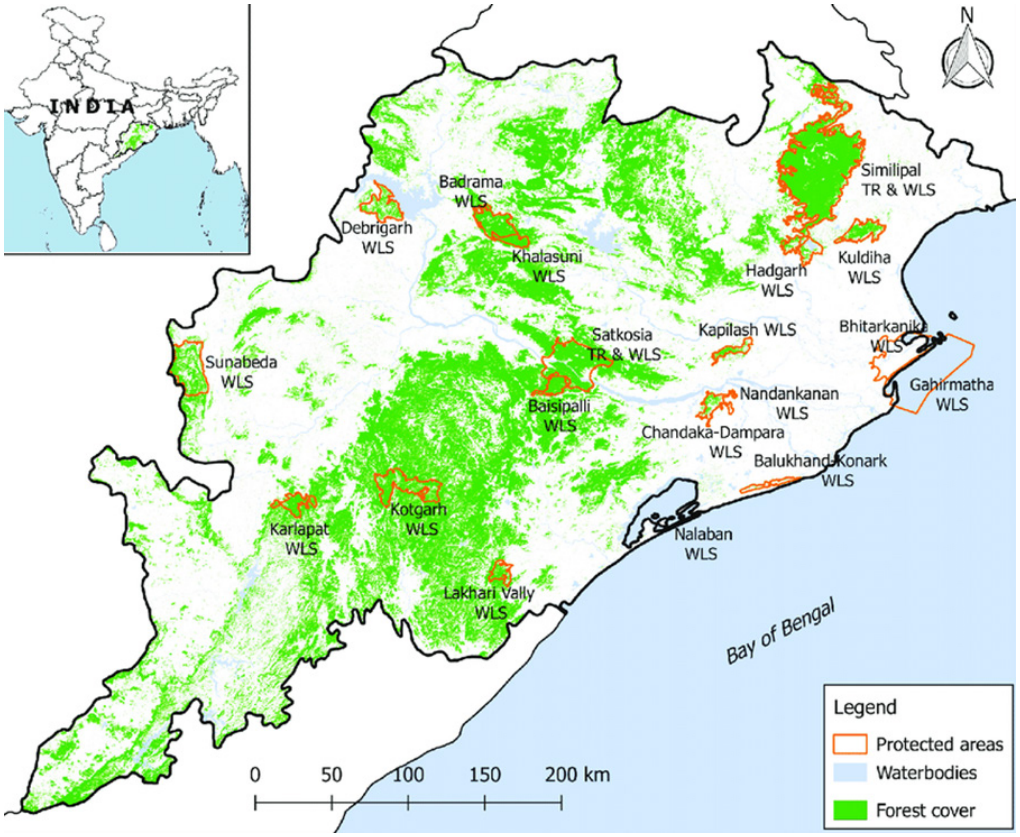


Table 5: Forest cover of Odisha

Source: ENVIS Centre of Odisha's State of Environment

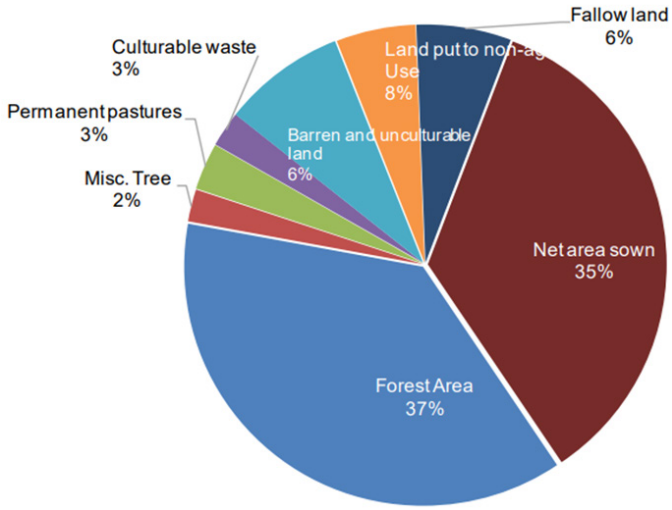
Recorded Forest Area	
Reserved Forest Area	26,329 sq km
Protected Forest	15,525 sq km
Unclassed Forest	16,282 sq km
Total	58,136 sq km
Of State's Geographical Area	37.34%
Of India's Forest Area	7.53%

Land Use Pattern

In 2021-22, the net sown area in the State of Odisha was 54.1 lakh hectares, comprising 35% of the total geographical area, showing a 1.5% increase from the previous year. Fallow lands, including current and other fallows, accounted for 6% of the total land in the State. The total gross cropped area, representing the total area sown once and/or more, saw a marginal increase of 0.3% in 2021-22 compared to the previous year, reaching about 85.6 lakh hectares. The land use pattern in Odisha for 2021-22 is illustrated in the Figure below.

Figure 15: Distribution of land use pattern during 2021-22 - Odisha

Source: Directorate of Agriculture and Food Production, Odisha



2.5.2 Land Degradation, Land Affected by Construction or Materials Extraction

Extensive iron, manganese, and limestone mining in Mayurbhanj, Keonjhar, and Baragarh districts and inadequate fly ash and red mud disposal have severely impacted Odisha. Reclamation efforts by mining authorities haven't restored normalcy. Occupational health hazards like pneumoconiosis, silicosis, and tuberculosis afflict miners. Tribal-dominated mining areas also face significant socio-economic and cultural consequences.

2.5.3 State's Estimated Emissions

Odisha's GHG emissions surged from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e (9.3% of India's GHG emission) in 2018, with an expected CAGR of 7.85%. Odisha's per capita emissions stands at 6.15t CO2e/capita whereas India's stands at 2.24t CO_2e/capita. The rise in emissions was mainly driven by increased energy sector emissions, as shown in Figure 1. Over the same period, the share of emissions from Industrial Processes and Product Use (IPPU) rose from 3% to 5%, while emissions from the Energy sector increased from 85% to 92% of total economy-wide emissions. Conversely, waste emissions decreased from 2% to 1%, and agriculture, forestry, and other land-use (AFOLU) emissions dropped from 10% to 2% in 2018 (see Figure 2).

Figure 16: Trends in GHG emissions of Odisha, 2005 to 2018

Source: Analysis of Greenhouse Gas Emissions from 2005 to 2018 by GHG Platform India

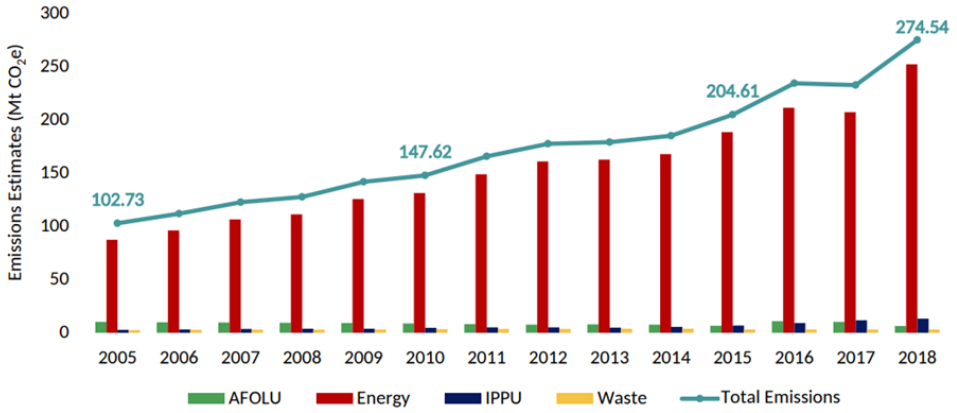
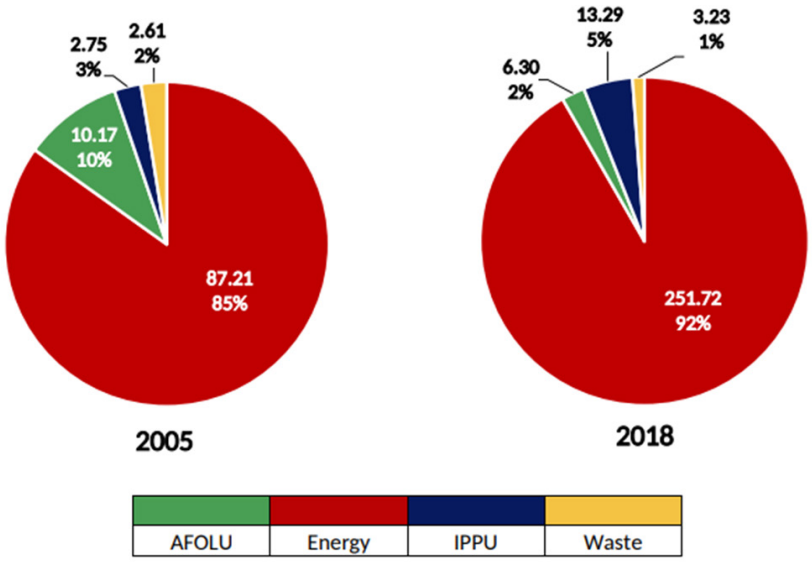


Figure 17: Odisha's sector-specific contribution (Mt CO_2e) and share in economy-wide GHG emissions

Source: Analysis of Greenhouse Gas Emissions from 2005 to 2018 by GHG Platform India



2.5.4 Water and Soil Pollution

Water Pollution

Water sources in Odisha include the Bay of Bengal, lakes like Chilika and Ansupa, and rivers such as Mahanadi, Subarnarekha, Baitarani, Rushikulya, Budhabalanga, Brahmani, Salandi, Kathajodi, Birupa, Kusabhadra, Daya, and various rivulets, covering groundwater, tanks, ponds, open wells, and tubewells.

Urban areas in Odisha significantly contribute to water pollution by discharging untreated domestic water into nearby ponds, tanks, and rivers through municipal drains. Cities like Bhubaneswar, Cuttack, Rourkela, Sambalpur, and Berhampur discharge substantial volumes of sewage effluents into rivers like Mahanadi, Kathajodi, Kuakhai, Daya, Brahmani, and Rushikulya, containing heavy metals, bacteria, and viruses. Industries, including paper, captive power plants, sugar mills, chlorine plants, phosphatic fertiliser, and chromite mines, also discharge effluents with various pollutants, such as heavy metals and chemicals, into rivers and water bodies, posing evident pollution risks in affected areas.

Soil Pollution

There are various means of soil pollution. Soil pollution in Odisha is increasing daily, resulting in poor crop stand and health hazards for human beings and animals. Major sources of soil pollution in Odisha are as follows:

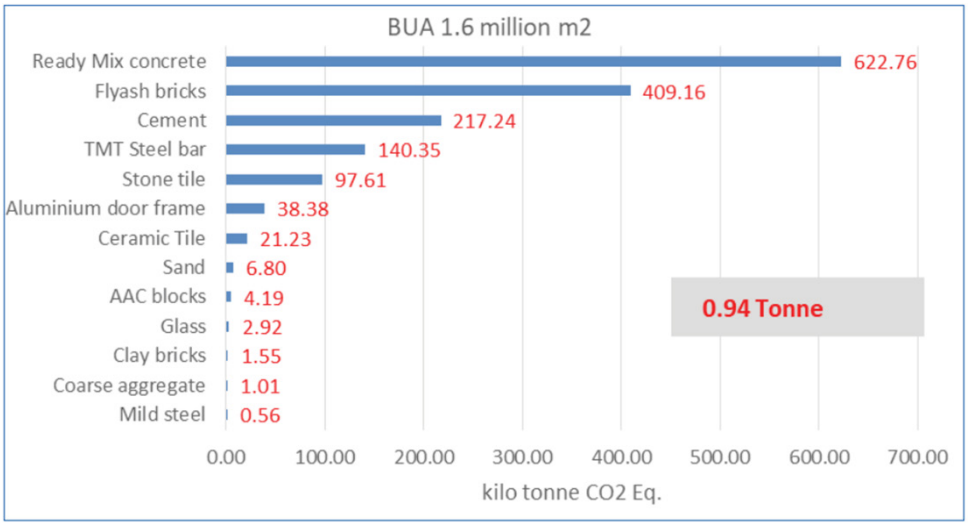
1. Overburdens of mines
2. Industrial effluents
3. Sewage Sludge
4. Fertilisers and pesticide application.

2.5.5 Emissions from the Building and Construction Sector

The use of concrete in buildings dominates CO_2 emissions, followed by fly ash bricks, accounting for 40% and 26% of total emissions, respectively. Cement alone accounts for 42% of total emissions at the raw material level, owing mostly to its use in concrete and mortar. The increasing number/percentage of RCC frame structures, which require 15-20% more cement per m2, also adds to the total rise in cement usage. Sand, which accounts for 33% of the flow of raw materials, contributes less than 2% of total emissions. This is because river sand is nearly exclusively used in buildings, consuming only transportation energy. However, it is essential to highlight that such large-scale usage of river sand has serious ecological consequences, such as shifting river channels (Mahanadi, Daya river) and a high chance of embankment cave-in, which might endanger the lives of people living in communities along the riverside.

Figure 18: CO_2 footprint of materials for 2179 residential projects in Bhubaneshwar

Source: Resource flow in Indian Cities-City profile of construction sector in Bhubaneshwar, 2020



Construction workers tying reinforcement for precast slabs

3. Urban Development and Spatial Planning

3.1 Population Growth & Urban Expansion

What is 'Urban' According to the Census of India?

The Census of India categorises 'Urban' based on two criteria.

- Firstly, the state government assigns a municipal status, such as a corporation, municipal council, notified town area committee, nagar panchayat, etc., to a settlement referred to as a statutory or municipal town in the census definition of urban areas.
- Secondly, a territory that doesn't have an urban civic status can be declared urban if it meets specific demographic and economic standards, such as a population of more than 5,000, a density of 400 persons per square kilometer, and a 75% male workforce in the non-agricultural sector.

3.1.1 Urbanisation Trends in India

The Office of the Registrar General and Census Commissioner of the Indian Institution of Population Sciences had previously predicted that the growth rate of the urban population in India would decrease from 2.75% annually between 1991-2001 to 2.23% between 2001-2011, with an estimated urban population of 358 million for 2011. Urban experts also believed India's urbanisation would slow down due to its exclusionary nature and lack of rural-to-urban migration (Bhagat, 2011)[2]. However, the 2011 Census showed unexpected results, with the urban population growing to 377 million at a rate of 2.76% annually between 2001-2011. The overall level of urbanisation in India increased from 27.7% in 2001 to 31.1% in 2011, indicating a 3.3 percentage point increase during 2001-2011, compared to a 2.1 percentage point increase during 1991-2001. It is important to note that India's economy grew from 6% annually in the 1990s to 8% in the first decade of the 2000s, highlighting the impact of economic growth on faster urbanisation during 2001-2011.

Table 6: Trends in urbanisation in India (1961-2011)

As the 1981 census was not conducted in Assam, and the 1991 Census was not held in Jammu and Kashmir, the Population of India included projected figures for the mentioned states in those periods.

Source: Census, 2011

Census Year	Urban Population (in a million)	Percentage Urban	Annual Exponential Urban Growth Rate
1961	78.94	17.97	-
1971	109.11	19.91	3.23
1981	159.46	23.34	3.79
1991	217.18	25.72	3.09
2001	286.12	27.86	2.75
2011	377.10	31.16	2.76

Table 7: Urban-rural population growth differentials (1971-2011)

Source: Census of India (over the decades)

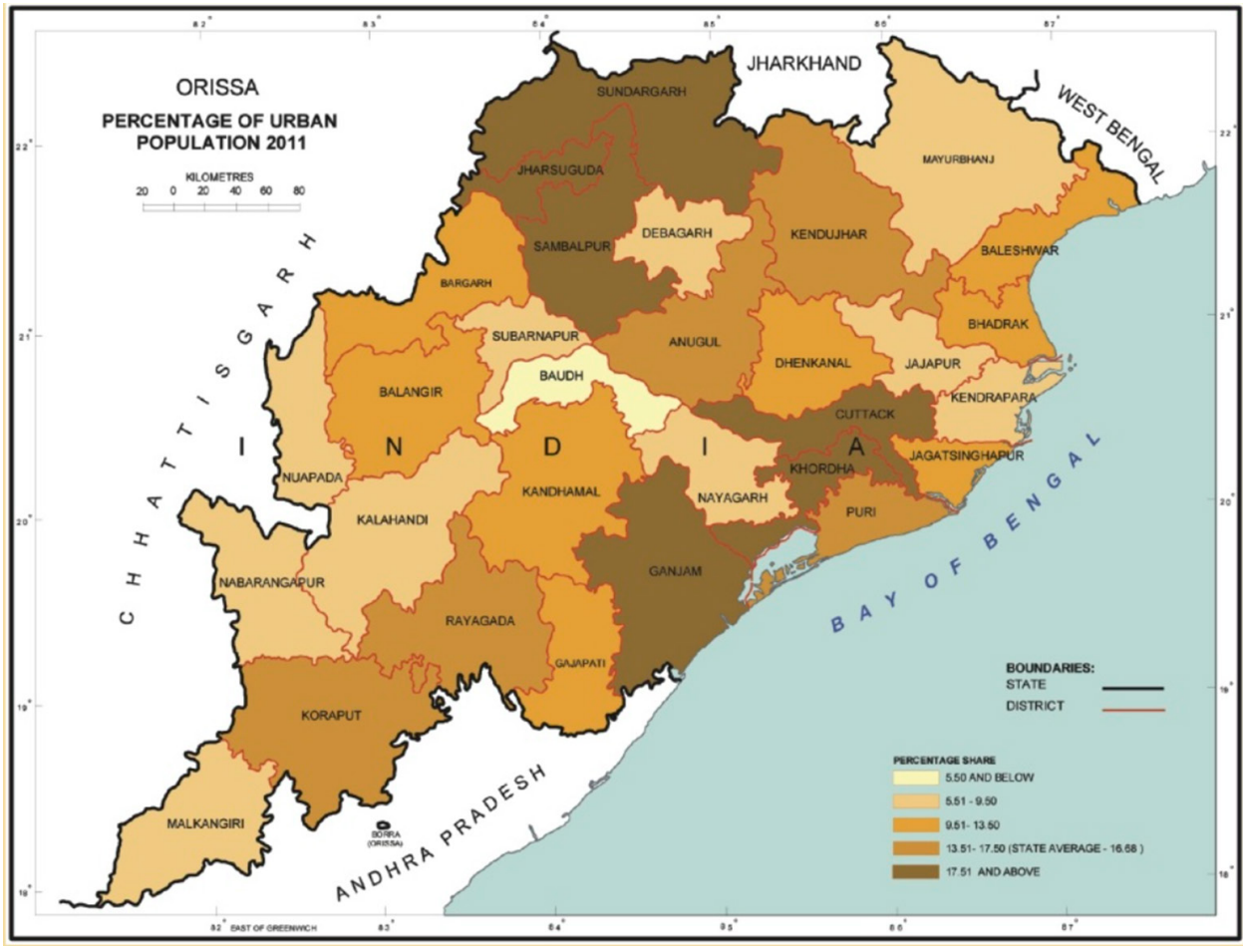
Decade	Rural	Urban	Urban-Rural Growth Differentials
1971-1981	1.76	3.79	2.03
1981-1991	1.8	3.09	1.29
1991-2001	1.69	2.75	1.06
2001-2011	1.15	2.76	1.61

As a state, Odisha has observed a different curve to urbanisation than the country. This report delves into the unique urbanisation trend of Odisha as compared to the rest of the country. It additionally sheds light on the factors that contribute to this trend.

3.1.2 Urbanisation Trends in Odisha

Figure 19: Odisha- percentage of urban population

Source: Census, 2011



According to the Government of India National Sample Survey conducted from 1981-2011, it can be analysed that in the past few decades, the growth rate of Odisha's population has varied unpredictably. While the growth rate was 6.38% during 1941-51, it increased significantly to 19.82% during 1951-61. However, it declined to 20.17% during 1971-81 and then slightly reduced further to 20.06% during 1981-91. In the decade of 1991-2001, the rate further decreased to 15.94%, which is lower than the national average of 21.34%.

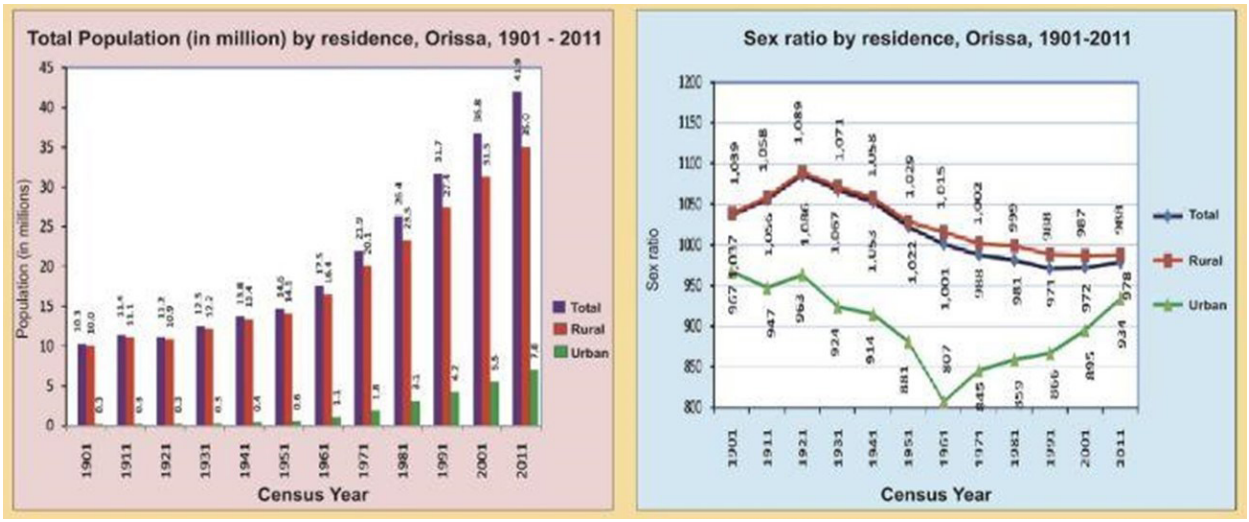
a. District-wise Urbanisation Trends in Odisha

Ganjam district has the highest population according to the 2001 census. The decadal growth rate of all districts except Gajapati district during the current decade (1991-2001) was lower than that of 1981-91. The district of Khurda had the highest decadal growth rate (24.97%), while Bolangir had the lowest (8.52%). The number of districts in Odisha increased from 13 in the 1991 census to 30 in the 2001 census, with three districts remaining the same and the other ten districts divided into 27.

Odisha has one of the lowest urbanisation rates in India, with only 14.97% of the population residing in urban areas. Among Odisha's districts, Khurda is the most urbanised due to Bhubaneswar's status as an administrative center with a high proportion of non-agricultural employment. Bhubaneswar (M. Corp) has a 100% urban population, which is significantly higher than the proportion of the district's total population. The town has experienced a high population growth rate since 1971-81 (107.80%) and 1981-91 (87.74%) due to migration from other parts of the state in search of better education and employment opportunities. (India, PCA-TOT: Primary Census Abstract Total,Orissa - 2001, 2001)[3]

Figure 20: Population and sex ratio- representation from 1901 to 2011

Source: Census of India (Trends)



According to the Census of India 2011, the population of Odisha is about 42 million, with an uneven geographic distribution. Six of the 30 districts have a population of 2 million and above, accounting for 36% of the state's population. Another 14 districts have a population of 1 million and above, accounting for another 48%. Therefore, nearly 84% of the total population resides in just 20 districts of the state. (India, censusindia.co.in, 2011)[4].

b. The Gendered Lens of Urbanisation in Odisha:

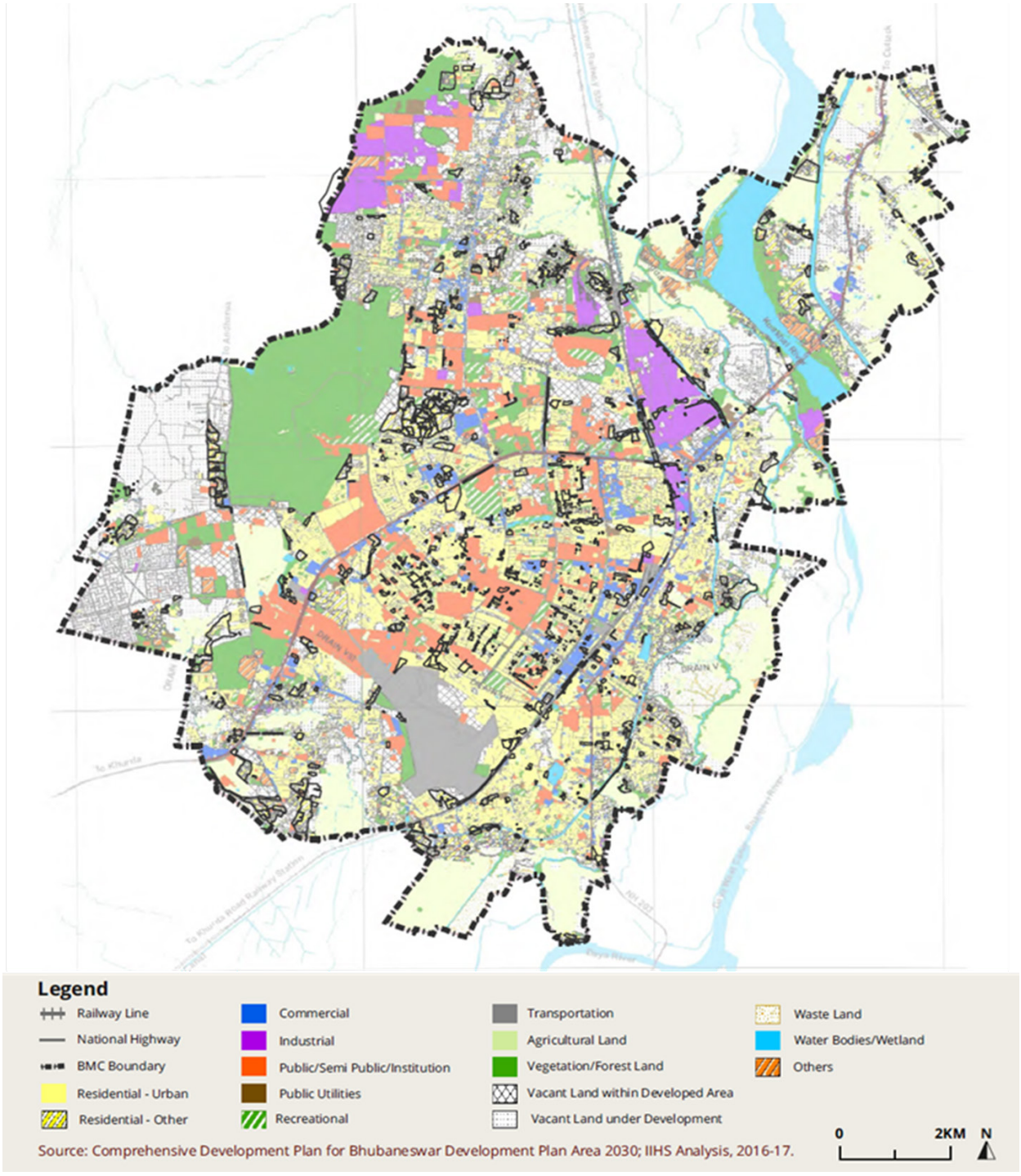
As per a study 'Women's Work in Response to Urbanisation: Evidence from Odisha' (Mitra, 2019) [5], it can be seen that there is a strong belief that urbanisation is often considered necessary for breaking down social and cultural barriers, enabling more women to enter the workforce, and creating job opportunities. However, in Odisha, a state with relatively low urbanisation, there is a higher rate of women's participation in the workforce. The relationship between urbanisation and work participation among women is not strongly evident across districts, particularly in urban areas. In rural areas, there is a subtle positive association with some exceptions. Essentially, urbanisation positively impacts rural women's participation in the job market, but urban areas need further infrastructural development in urban spaces to increase women's participation. The growth effect on women's work participation in urban areas is primarily negative, indicating a gender bias in employment opportunities. The new jobs in high-productivity sectors require technology and skills, which women may need more time to access to due to age-old taboos. Additionally, social norms often perceive women's participation in the job market as low status, despite educated women being more likely to find white-collar rather than blue-collar jobs. On the demand side, businesses prefer male workers due to perceived costs associated with female workers, such as maternity benefits and leave.

3.1.3 Nature of Urbanisation in Bhubaneswar

Initially planned for 40,000 people over 16.41 square kilometers, the city now accommodates around 750,000 people in approximately 135 square kilometers. During 50 years, from 1951 to 2001, the municipality area has increased from 26.09 Km2 to 137.7 Km2. The development process has extended beyond the initial plan, resulting in the city's expansion in all directions, including areas like Chandrasekharpur, Kaling Vihar, Old Town, and regions adjacent to the Daya West Canal. (QoC, 2023)[6].

Figure 21: Land-use in Bhubaneswar; Source: Comprehensive development plan area 2030

Source: IIHS Analysis, 2016-17



This growth has primarily been driven by in-migration and the city's development as a major center for trade, commerce, technology, and education. The Bhubaneswar Urban Development Authority was established under the Orissa Development Authority Act of 1982 to manage the rapid growth. Land transformation has occurred on a large scale, with agricultural land, forest land, and riverbanks being converted for urban uses, including residential areas, plotted land developments, and institutional purposes such as educational institutes. The availability of natural resources developed transport facilities, and the presence of urban centers in the vicinity have facilitated this land transformation. (The Odisha Development Authorities Act, 1982, 1982) [7]

In the past decade, around 15,000 hectares of agricultural land have been converted to residential land in the Khorda district (which now consists of Bhubaneswar). However, the expansion has primarily occurred towards the city's periphery, encroaching upon fertile agricultural land, archaeological sites, wildlife sanctuaries, and protected forest areas. The reduction in forest area from 90.27% in 1970 to 62.72% in 2005 highlights the ecological impact of urbanisation (MoHUA, 2007). These challenges call for sustainable and environmentally conscious urban planning and development strategies to mitigate the adverse effects of urban growth on the fragile ecosystem of Bhubaneswar and its periphery.

Table 8: Population detail and growth trends in population of Bhubaneswar city

Source: City Development Plan, Bhubaneswar, Odisha

Census Year	Population	Decadal Growth (%)	Area (sq.km.)	Density per sq. km.
1951	16512	-	25.90	638
1961	38211	131.41	50.25	760
1971	105491	176.07	65.03	1622
1981	219211	107.80	92.91	2359
1991	411542	87.74	124.74	3299
2001	648032	57.46	135.00	4800

Table 9: Key socio-economic features- Odisha and Bhubaneswar (As per city development plan report, 2018)

Particulars	Odisha	Bhubaneswar
Urban Sex Ratio	895	796
Literacy Rate (percent)	81	78
Worker's participation- urban (percent)	30.62	33.3
Proportion of main workers to total workers (percent)	89.8	94.76

Table 10: Urban Growth in India and Odisha

Source: Census of India (Trends)

Current Year	No. of Urban Area/Town		Percentage of Urban Population to Total Population	
	India	Odisha	India	Odisha
1901	1916	14	10.84	2.47
1911	1908	18	10.29	2.42
1921	2048	20	11.18	2.52
1931	2220	21	11.99	2.54
1941	2427	29	13.86	3.00
1951	3060	39	17.29	4.06
1961	2700	62	17.97	6.32
1971	3126	81	19.91	8.41
1981	4029	108	23.34	11.79
1991	4689	124	25.70	13.38
2001	5161	138	27.78	14.97
2011			31.16	

Urban Planning in Bhubaneswar

Bhubaneswar has a total of 8 distinct plans, as shown in Table 11 which are concurrently in progress, all dedicated to the city's comprehensive or sector-specific development. These plans have been systematically divided into three clusters based on their sectoral orientation and institutional foundation. Notably, the first cluster consists of plans with a legally mandated status, making their enforcement obligatory. Among these, the Comprehensive Development Plan and the Perspective Plan – VISION 2030 for Bhubaneswar – Cuttack Urban Complex hold legal significance, operating in accordance with the Odisha Development Authority Act, 1982. This act sets the guidelines for planned land and infrastructure development across all cities in the state.

Table 11: A list of planning documents prepared for Bhubaneswar city with their goals, influence area, and executing authorities

Source: Praharaj et al., 2018

Plan	Goal	Action area	Implementing authority
Perspective Plan - VISION 2030 for Bhubaneswar - Cuttack Urban Complex	To envision Cuttack and Bhubaneswar as twin cities playing a complimentary role and developing the Urban Complex to a world class centre	Bhubaneswar-Cuttack Urban Complex comprising the two major urban centers over an area of 720 sq. km.	Housing and Urban Development Department, Government of Orissa
Comprehensive development plan	To regulate and guide urban growth in the region focussing on improving quality of life and creating economic opportunities	Bhubaneswar development plan area covering 419.1 sq. kms.	Bhubaneswar Development Authority
City Development Plan (CDP)	To develop a vision and future strategy for infrastructure development in the city	Bhubaneswar development area of 233 sq. km. including the municipal corporation and its peripheries	Bhubaneswar Municipal Corporation
City Sanitation Plan (CSP)	To develop sanitation infrastructure along with generating awareness in the community and encouraging public private partnerships in the sector.	Bhubaneswar development area of 233 sq. km. including the municipal corporation and its peripheries	Bhubaneswar Municipal Corporation
Environmental Management plan	To assess the environmental stress of the city from study of land use plan, pollution sources and propose an action plan for area based interventions	Bhubaneswar development area of 233 sq. km. including the municipal corporation and its peripheries	Odisha Pollution Control Board
Slum free city plan	To upgrade/ redevelop/ relocate existing slums and prevent future slum formations	Bhubaneswar Municipal Corporation covering 186 sq. km	Bhubaneswar Municipal Corporation
City Disaster Management Plan	Adopt a regional strategy to reduce disaster risks by enhancing resilience to disasters and climate change	Bhubaneswar development area of 233 sq. km. including the municipal corporation	Bhubaneswar Municipal Corporation and State Disaster Management Auth.
Smart City Plan	To Develop Bhubaneswar as a transit-oriented city following livable and Eco-city principles with a strong economic centre attracting technology and knowledge-based enterprises	Bhubaneswar development area of 233 sq. km. including the municipal corporation and its peripheries	Special Purpose Vehicle (50:50 equity share between state and city)

While these plans were formulated under the supervision of the Housing and Urban Development Department, their execution falls under the purview of the Bhubaneswar Development Authority, the local agency responsible for planning (Praharaj et al., 2018).

3.1.4 Population, Growth rate & Projections (Demand for Housing)

With a population of over 43 million, Odisha has had a 27% yearly increase in urbanisation over the past ten years. The state has faced several difficulties because of this fast urbanisation, including a **5,02,000-home shortfall** as of 2022 according to data from the Odisha Urban Housing Mission, the Housing for All Plan of Action (HFAPoA) 2019. Also, Odisha is expected to have 44.29 million residents by March 2022, making it the **eleventh-most populous state** in India, according to the Unique Identification Aadhar India, updated as of 31 March 2022 *(Executive Summary (OES)-2022-23 Final, n.d.)*.

3.1.5 Average Household Composition (Desegregated Urban and Rural)

According to NFHS-4 (National Family Health Survey), 2015–16, 16% of households in Odisha are in urban areas. In Odisha, families typically have four people living in them. 11 percent of the population lives in families with a woman as the head, making up 14% of all households.

3.1.6 Population Density

According to the 2011 Census, Odisha has a lower density than the national average of 382 people per square kilometre, at **270**. Orissa's density in 2001 was 236 per square kilometre, compared to the national average of 324 per square kilometre. In Odisha, the Khordha district, which houses the state capital of Bhubaneswar, has the highest population density. The district-wise population density of Odisha is given in the table below.

Affordable housing construction near Utkal Hospital, Lumbini Vihar, Bhubaneshwar

Table 12: District wise population density of Odisha, 2011

Source: Census of India 2011

S.No.	District Name	Population	Area (in KM)	Density
1	Khordha	22,51,673	2,813	**799**
2	Jagatsinghapur	11,36,971	1,668	**681**
3	Cuttack	26,24,470	3,932	**666**
4	Jajapur	18,27,192	2,899	**630**
5	Balasore	23,20,529	3,806	**609**
6	Bhadrak	15,06,337	2,505	**601**
7	Kendrapara	14,40,361	2,644	**545**
8	Puri	16,98,730	3,479	**488**
9	Ganjam	35,29,031	8,206	**429**
10	Subarnapur	6,10,183	2,337	**279**
11	Jharsuguda	5,79,505	2,114	**274**
12	Dhenkanal	11,92,811	4,452	**268**
13	Bargarh	14,81,255	5,837	**253**
14	Balangir	16,48,997	6,575	**251**
15	Nayagarh	9,62,789	3,890	**247**
16	Mayurbhanj	25,19,738	10,418	**241**
17	Nabarangapur	12,20,946	5,291	**230**
18	Kendujhar	18,01,733	8,303	**217**
19	Sundargarh	20,93,437	9,712	**214**
20	Anugul	12,73,821	6,375	**199**
21	Kalahandi	15,76,869	7,920	**199**
22	Sambalpur	10,41,099	6,624	**158**
23	Nuapada	6,10,382	3,852	**157**
24	Koraput	13,79,647	8,807	**156**
25	Baudh	4,41,162	3,098	**142**
26	Rayagada	9,67,911	7,073	**136**
27	Gajapati	5,77,817	4,325	**133**
28	Debagarh	3,12,520	2,940	**106**
29	Malkangiri	6,13,192	5,791	**106**
30	Kandhamal	7,33,110	8,021	**91**
Average population density of Odisha				**270**

3.2 Statutes, Rules, Laws, and Ordinances in Relation to Planning & Construction at National level

India's building and construction sector is regulated by a range of statutes, laws, and ordinances to ensure safety, quality, environmental compliance, and orderly development. The following are some of the key regulations governing the sector at the national level:

a. The National Building Code (NBC)

The National Building Code is a comprehensive document that provides guidelines and standards for building construction, including building materials, structural design, fire safety, plumbing, electrical installations, and accessibility. The NBC is not a statutory code, but it is widely adopted by state and local authorities for regulating construction practices (Bureau of Indian Standards, 2018).

b. Real Estate (Regulation and Development) Act, 2016 (RERA)

RERA aims to bring transparency, accountability, and consumer protection to the real estate sector. It requires developers to register their projects with the respective state's Real Estate Regulatory Authority, adhere to approved project plans, and provide timely possession to buyers. RERA also mandates the disclosure of project details and prohibits unfair trade practices.

c. Environmental Regulations in Construction

Construction projects are subject to several environmental laws in India:

- The Air (Prevention and Control of Pollution) Act 1981
- The Water (Prevention and Control of Pollution) Act 1974
- The Environment Protection Act 1986

The Environmental Impact Assessment (EIA) Notification 2004 mandates obtaining 'no objection' from the relevant government authorities for projects meeting certain criteria before receiving clearance from the Ministry of Environment, Forest and Climate Change. Approvals necessitate adherence to environmental standards, afforestation, and other conditions. These approvals address environmental considerations, land use of protected areas, waste disposal, and pollution mitigation (Association of Corporate Counsel, 2016).

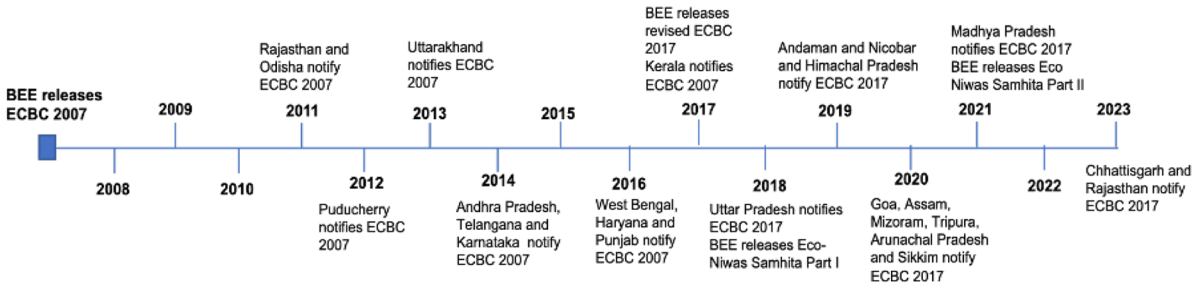
a. Building Bye-Laws

State and local authorities formulate building bye-laws that outline construction regulations specific to their jurisdictions. These bye-laws cover aspects such as setbacks, floor area ratio, building heights, open spaces, and fire safety measures (Town and Country Planning Organisation & Ministry of Urban Development (GoI), 2016).

b. Energy Conservation Building Code (ECBC)

Figure 30: ECBC notification timeline across states in India

Source: BEE and NRDC, 2023



The Bureau of Energy Efficiency (BEE), under the Ministry of Power, released the Energy Conservation Building Code in 2007 (later amended in 2017). The ECBC sets minimum efficiency standards for new commercial buildings and serves as a model for states to modify, adopt, and implement energy codes as a state law. It provides current and futuristic advancements in building technology to further reduce operational energy consumption and promote low-carbon growth by setting parameters for builders, designers, and architects to integrate renewable energy sources in building design with passive design strategies. As of April 2023, 23 states have notified the ECBC. Implementing ECBC guidelines is estimated to achieve a 50 percent reduction in energy use by 2030 (Madan, 2023).

ECO Niwas Samhita (ENS) 2018 (Part 1) – The Energy Conservation Building Code for Residential Buildings was launched by the Ministry of Power in 2018. Part 2 of ENS was launched in 2021. It is "an energy conservation residential building code developed to improve residential building's thermal performance and reduce its energy consumption and carbon emissions, setting minimum performance standards for building envelope and electromechanical components" (AEEE, 2022).

c. Construction Contracts and Regulatory Landscape in India

Construction projects in India operate under the framework of the Indian Contract Act, 1872, which necessitated agreements adhering to key principles such as competent parties, free consent, lawful consideration, and lawful objectives. To ensure legality and enforceability, construction contracts must align with these tenets (Ibid).

The Indian construction sector lacks a standardised contract form. Although contracts by the International Federation of Consulting Engineers (FIDIC), the Institute of Civil Engineers and the Indian Institute of Architects find use, government bodies also adopt their own contract templates. Consequently, a lack of uniformity prevails in contract terms and formats within the construction industry (Ibid). Economic liberalisation from the 1990s led to increased private sector involvement in infrastructure projects through the public-private partnership (PPP) model. Most PPP projects employ item rate contracts, where contractors specify unit prices for construction work items. Private entities subsequently procure goods in accordance with negotiated contract terms (Ibid).

d. Policies for Procurement

Government Procurement Regulations and Processes

Government procurement in India is guided by the General Financial Rules 2017, the Manual on Policies and Procedures for the Purchase of Goods and Services, and the Central Vigilance Commission guidelines. In 2017, the Public Procurement (Preference to Make in India) Order mandated preference for domestically produced goods. This order classifies suppliers based on local content percentages, fostering local manufacturing. However, the order only applies to certain goods, services, and works (Ibid). Procurement decisions can be based on recommendations from purchase committees, rate contracts with registered suppliers, or through competitive bidding processes. The competitive bidding process, particularly open competitive bidding, is a prevalent approach for large-scale infrastructure projects, with variations in bidding methods determined by project characteristics.

Gem (Government e-Marketplace) is India's online platform launched by the government for procurement of goods and services by various ministries and organisations. It facilitates transparent, efficient, and cost-effective procurement processes for government agencies, promoting e-commerce and supporting the Make in India initiative. It fosters digital transactions and supports the government's initiatives for ease of doing business and promoting entrepreneurship.

Government Procurement Framework and Private Participation

Economic liberalisation paved the way for the expansion of private involvement in infrastructure projects, primarily via PPPs. Notably, PPP projects in construction often follow item-rate contracts, where contractors quote unit prices for each construction task, and private entities source materials based on contract terms.

e. Integration of Sustainable Practices

In 2017, the government introduced the Public Procurement (Preference to Make in India) Order to promote local manufacturing. The order mandates the utilisation of suppliers producing or sourcing goods within India for specified categories. Amendments in 2020 introduced classification based on the percentage of local content, urging suppliers to meet Class-I or Class-II certification criteria, emphasising local content thresholds of 50% and 20%, respectively.

f. Green Public Procurement Initiatives

Green Public Procurement (GPP) initiatives have been emerging gradually. The Ministry of Environment and Forests established GPP guidelines in 2011, and in 2012, the Government introduced the Draft Public Procurement Bill 2012, outlining criteria such as price, operating costs, and environmental attributes. The Ministry of Micro, Small, and Medium Enterprises also enforced an executive order requiring 20% procurement from micro and small enterprises.

g. Task Force on Sustainable Public Procurement

A Task Force on Sustainable Public Procurement was formed by the Ministry of Finance in 2018 to review global best practices, assess the status of GPP across Indian government entities, create a sustainable procurement action plan, and recommend product/service categories for GPP implementation.

h. Scope of Policy Implementation

The Sustainable Public Procurement Task Force's recommendations encompass all central Indian government ministries, departments, and central public-sector undertakings (UNEP 2016). Local governments, ministries, and departments in India have embarked on GPP initiatives, evident in endeavours such as compact fluorescent lighting (CFL) programs. Indian Railways, for instance, adopted a pioneering approach in 2008 by replacing incandescent lamps with energy-efficient CFLs, demonstrating lifecycle cost benefits despite initial cost disparities (OECD 2015). Despite these initiatives, a comprehensive GPP strategy remains fragmented (CII 2012). While certain public entities like Indian Railways, Bharat Heavy Electricals Limited, National Thermal Power Corporation, and Indian Oil Corporation have begun integrating environmental and energy-efficient criteria into procurement, these efforts exist in isolation and lack scalability across government entities (Modak P. 2014).

i. Encompassed Product Categories

The Sustainable Public Procurement task force's scope extends to six key product categories: public works (brick, steel, cement), electrical appliances, information technology (computers & peripherals, photocopiers, telecom), pharmaceuticals (bulk drugs), paper, office furniture, and lighting. These categories were chosen for their environmental impact, usage volumes, and substantial public spending allocation (IISD 2012).

j. Eco-mark and Eco-labelling

In 1991, India initiated the voluntary Eco-Mark eco-labelling scheme, which focuses on both environmental and product quality criteria (CII 2012). "The Ecomark Scheme covers various product categories like Soaps and Detergents, Paints, Food Items, lubricating oils, Packaging materials/Package, Architectural Paints and Powder Coatings, Batteries, Electrical and electronic goods, Food Additives, Wood Substitutes, Cosmetics, Aerosols and Propellants, Plastic Products, Textiles, Fire-extinguisher, Leather and Coir & Coir Products" (BIS, accessed September 2023). However, eco-labels and environmental standards have yet to gain significant traction in India's public procurement domain, and the Eco-Mark label has not been widely adopted by manufacturers or buyers (UNEP 2013).

While public procurement constitutes approximately 30 percent of India's GDP, a centralised GPP program is absent, rendering GPP extent and impact estimates unavailable. Each government organisation is responsible for formulating its own targets and monitoring mechanisms to ensure compliance with the Ministry of MSME's procurement policy (UNEP 2016). Nevertheless, published information regarding these internal agency processes is lacking.

3.3 Urban & Rural Fabrics

3.3.1 Share of Land Occupied by Urban vs. Rural

According to the 2011 Census of India,

- Population distribution- Rural-Urban: 68.8% - 31.2%

- Out of a total increase of 181.4 million persons during 2001-11, the contribution of urban areas (91.0 million) is higher than that of Rural areas (90.4 million).

The decadal growth and movement to urban spaces in India have consequently shifted the nature of the land use pattern in the country. Over the past two decades, urban and rural differences have become evident. The land share varies with the shift in population density and development strategies. The map below represents the urban extents of the land shared in the country. Urban extents illustrate the shape and area of urbanised places, defined spaces with 5000 or more inhabitants.

Figure 22: Urban extents in India

Source: NASA, 2007

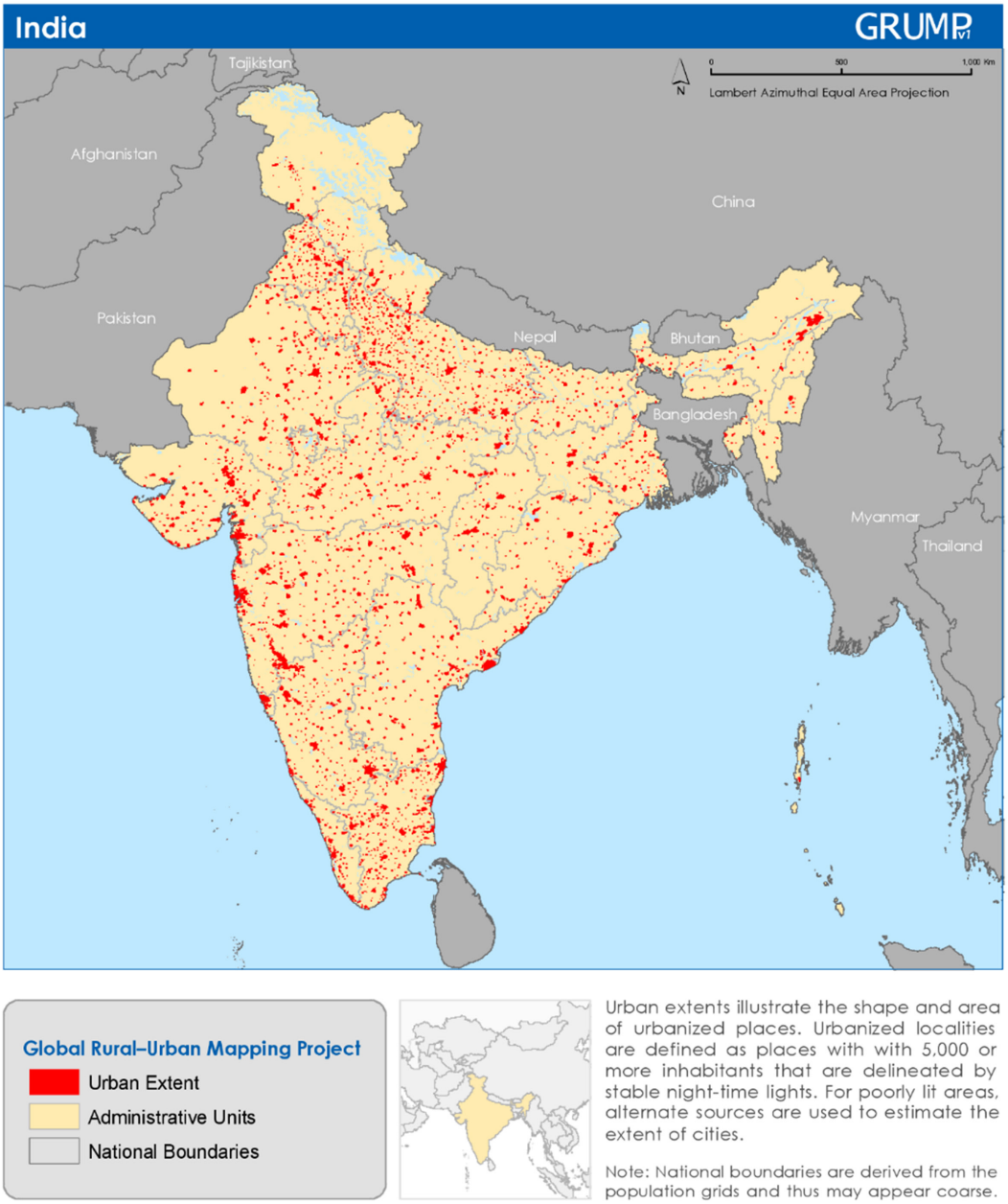


Table 13: Land use distribution in urban centres

Source: Ministry of Housing and Urban Affairs, URDPFI Guidelines, 2015.

S.No.	Land Use Category	Percentage of Developed Areas (In Cities)			
		Small	Medium	Large	Metropolitan
1	Residential	45-50	43-48	36-39	36-38
2	Commercial	2-3	4-6	5-6	5-6
3	Industrial	8-10	7-9	7-8	7-8
4	Public & Semi-Public	6-8	6-8	10-12	10-12
5	Recreational	12-14	12-14	14-16	14-16
6	Transport & Communication	10-12	10-12	12-14	12-14
7	Agriculture, Water Bodies	3-17	3-17	5-16	5-16
Total developed area		100	100	100	100

The Land-use Pattern in Odisha

The Odisha State, according to Odisha's State of Environment ENVIS Centre (a unit of Forest & Environment Department, Odisha), broadly divides the state into four physiographic zones, namely coastal plains, central tableland, northern plateau, and Eastern Ghats. The total geographical area of the state is 155.71 lakh hectares, out of which 58.13 lakh hectares is a forest area, 4.82 lakh hectares of miscellaneous tree & groves, 4.43 lakh hectares of permanent pasture, 3.92 lakh hectares of culturable wasteland and 8.43 lakh hectares of barren & unculturable land. The State has a cultivated area of 62 lakh hectares, of which 27 lakh hectares is high land, 19 lakh hectares medium, and 16 lakh hectares low land.

As per the report of Odisha Remote Sensing Application Centre of 2002, the water body covers an area of 230104.36 hectares. The Wastelands Atlas of India – 2000 reports shifting cultivation area in the state to 10014.07 hectares and mining industrial wastelands of 35.45 hectares. This area is increasing gradually, according to various published reports.

As per the 2001 Census report, the number of permanent, semi-permanent, and temporary houses in the state are 2.1365, 1.9359, and 3.4915 million, respectively. The average household size is 0.0045 persons per thousand, with an average of 4.8 members per household.

Land Use in Bhubaneswar

The data below presents the shift in land use, an approximate loss of 16% in vegetation cover from 1991-2021, and a nearly 24% increase in the built-up area during the same years. The increasing population and the changing socio-economic status of the city can be identified as the major drivers of the visible shift.

In 1968, adhering to the increasing population, authorities designed the City Development Plan 1968 to promote a more dynamic growth of the economy, aiming to increase the production of goods and services due to an increase in demand, increasing employment opportunities, and enabling the capital city to play its role effectively as the centre of administration, institutions, and tourism while also retaining the state's foray of traditions as the temple city. The old city of Bhubaneswar has also proliferated during the last few decades, creating several problems like congestion, ad-hoc construction, and disrupted mobility.

Table 14: Land use land cover classes

Land Use/Land Cover Classes	Features Description
Built-up Land	Residential, commercial and services, industrial, recreational, transportation, communication and utilities, educational institutes, cantonments, reclaimed land, slum areas, quarrying/mining area
Vegetation	Evergreen forest, deciduous forest land, mixed forest land, shrub/degraded vegetation
Water Bodies	River/Stream, Canals/Drains, Ponds, Lakes, Reservoirs
Wastelands	Salt-affected areas, gullied/ravenous land, water-logged areas, undulating land with or without scrub, sandy areas, rock outcrops
Agricultural Land	Cropland, fallow ground, and plantations

Figure 23: Mapping the land use change in Bhubaneswar from 1991 to 2021

Source: Growth, Development and planning of Bhubaneswar, Routray et al.

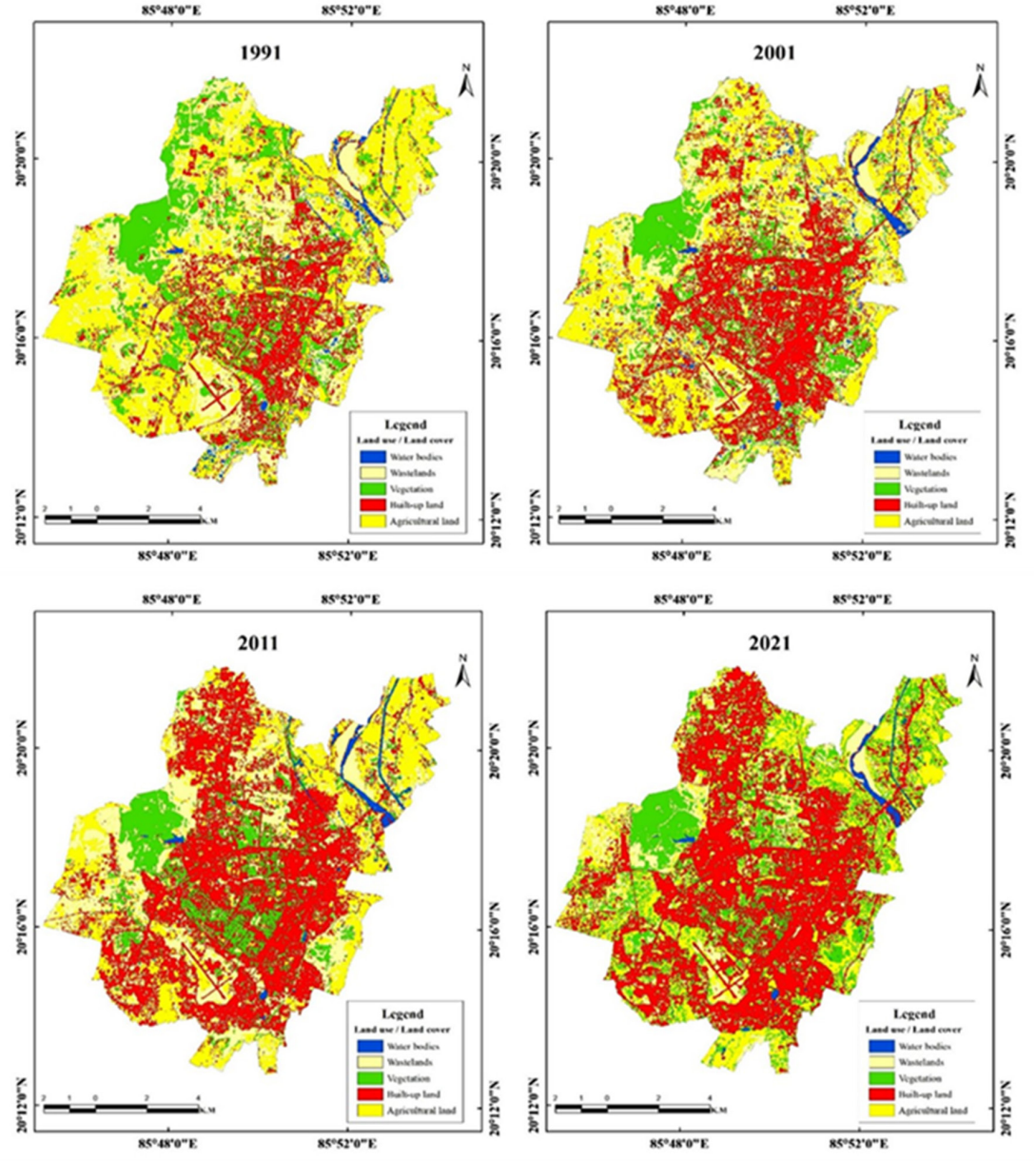


Table 15: Agencies responsible for land development and management in Bhubaneswar

Source: Based on SAC Technical Report 1999: SAC/RESA/TR-3/July 1999

S.No.	Type of Function	Organisations
A.	Urban development and planning, policy framework and guidelines	1. Housing and Urban Development Department 2. Directorate of Town Planning
B.	Leasing of the government land	1. General Administration Department with the assistance of Directorate of Town Planning
C.	Land record	1. Office of the Tahsildar
D.	Land Registration	1. Office of the Sub-Registrar (Land Registration)
E.	Infrastructure development	1. Roads and Buildings Department 2. Public Health Department 3. Odisha State Electricity Board 4. Bhubaneswar Municipal Corporation 5. Public Works Department 6. Industrial Development Corporation 7. Telecommunication
F.	Land and Housing Development	1. Odisha State Housing Board 2. Bhubaneswar Development Authority 3. Odisha State Cooperative Housing Corporation 4. Business Developers
G.	Planning and development control	1. Bhubaneswar Development Authority

3.3.2 Urban Population Ratio & Urbanisation Growth Rate

Rural Odisha's population increased 2.5 times from 140.5 lakh (1951) to 349.7 lakh (2011) and is projected to be 384.7 lakh by 2031. Urban Odisha's population grew 12 times from 5.9 lakh (1951) to 69.8 lakh (2011), estimated to reach 98.5 lakh by 2031. Rural India's population increased 2.8 times (1951 to 2011), while urban India's population grew 6 times (as shown in the table below).

Table 16: Share of urban & rural population trends- Odisha and India

Source: Census of India from 1951 to 2011, *Projected Population, MoHFW, GoI

Year	Odisha			Urban (percent)	India			Urban (percent)
	Population (in lakh No)				Population (in lakh No)			
	Rural	Urban	Total		Rural	Urban	Total	
1951	140.5	c	146.5	**4.1**	2986.4	624.4	3610.8	**17.3**
1961	164.4	11.1	175.5	**6.3**	3603	789.4	4392.4	**17.9**
1971	201	18.5	219.5	**6.4**	4390.5	1091.1	5481.6	**19.9**
1981	232.6	31.1	263.7	**11.8**	5238.7	1594.6	6333.3	**23.3**
1991	274.6	42.4	316.6	**13.4**	6288.6	2175.7	8464.2	**25.7**
2001	312.9	54.2	367.1	**14.9**	7426.2	2861.2	10287.4	**27.8**
2011	349.7	69.8	419.5	**16.7**	8334.6	3767.3	12101.9	**31.2**
2021*	373.1	84.9	457.9	**18.5**	8950.4	4721.4	13671.73	**34.5**
2031*	384.7	98.5	483.1	**20.4**	9239.1	5577.5	14816.57	**37.6**

About 16.69% of Odisha's total population resides in urban areas. Odisha's urban population grew by 26.94% between 2001 and 2011 and is predicted to continue to grow. In Odisha's urban areas, there were 932 females for every 1000 males.

Table 17: Odisha's large metropolitan regions

Source: https://www.census2011.co.in/

Large Metropolitan Region	Total Population (2011)	Male (2011)	Female (2011)	Projected Total Population (2023)	Projected Total Population (2031)
Bhubaneshwar	8,86,397	4,68,577	4,17,820	12,21,000	15,41,000
Cuttack	6,53,149	3,38,788	3,14,361	9,00,000	11,37,000
Raurkela	5,52,239	2,89,925	2,62,314	7,60,000	9,58,000

The remaining 83.31 percent of the people in Odisha state's total population reside in rural villages. In Odisha, the rural population grew at a pace of 11.77% over the course of this decade (2001–2011). The female sex ratio per 1000 males was 989 in Odisha's rural areas.

3.3.3 Type of Built Environment

1. **Urban Odisha:** Urban areas in Odisha, including cities like Bhubaneswar, Cuttack, and Puri, boast a continuous and dense built environment. These centres are characterised by a higher concentration of buildings, infrastructure, and amenities, reflecting urbanisation and economic activities. Modern structures, high-rise buildings, and commercial complexes have emerged in recent years.

Figure 24: Bhubaneshwar city in Odisha

Source: https://urbanupdate.in/housing-urban-development-department-of-odisha-receives-hudco-award/

2. **Rural Odisha:** Rural areas in Odisha feature a scattered and less dense built environment. Traditional settlements consist of clustered homes surrounded by agricultural fields. The architecture is influenced by local materials and culture, with traditional mud, thatch, or brick houses. These areas maintain a close connection to nature and agriculture.

Figure 25: Khond village in the hinterland of Odisha

Source: https://www.istockphoto.com/photo/khond-village-in-orissa-gm1392189226-448516559

3.4 Informal Settlements

3.4.1 Urban Population Living in Informal Settlements (Slum Areas)

According to the Odisha Economic Survey 2019-20, Odisha has the lowest slum population in the country, standing at 3.72% of the total state population, a decline from 1993 levels. Despite rapid urbanisation between 2001 and 2011, with the emergence of class IV and class III towns and cities accounting for 35.06% and 25% of the population, respectively, the number of people living in slums is only 1.56 million. Of this, 0.8 million are male, 0.76 million are female, and 0.19 million are children. The cities of Bhubaneswar and Cuttack have the highest slum populations, each with 1.64 lakh residents. Andhra Pradesh has the highest proportion of people living in slums at 12.04%, followed by the National Capital, New Delhi, and Puducherry, as per the survey.

3.4.2 Estimation of Public, Private, and Informal Housing Provision

Table 18: Housing demand assessment of Bhubaneshwar

Source: Projects under Pradhan Mantri Awas Yojna for Economically Weaker Sections (EWS). Bhubaneswar Development Authority, Government of Odisha. (2015)

S No.	Category	Sub Category	Type	No. of Households	Total Population
1	Existing Housing Shortages (2015)	Slum Redevelopment	New	61570	231457
			Upgradation	14095	55342
		Affordable Housing Non-Slum Poor	New Houses	17171	64392
			Rental Housing	9786	36697
2	Sub Total			**102622**	**387888**
3	Projected Affordable Housing Requirements (2022)		Inclusionary Zoning	9921	26872
			PPP Model	19500	75000
			Public Housing	19500	75000
4	Sub Total			54442	198956
5	Sub Total			**157064**	**586844**

3.5 Walkability & Mass Transit

3.5.1 Access to Pedestrians

The Odisha state government has prioritised walkability by constructing and maintaining footpaths and pedestrian crossings, implementing road safety awareness campaigns, managing traffic effectively, promoting non-motorised transport, and focusing on walkability in Smart City development plans. They also emphasise urban planning for walkable neighbourhoods and revitalising public spaces and green areas.

3.5.2 Access to Public Transport

1. Road: In 2021-22, OSRTC (Odisha State Road Transport Corporation) provided safe transport with 367 buses on 267 routes and an average fleet of 596, carrying 56.7 lakh passengers. They procured 180 new buses, including 10 luxury Volvo ones, and planned 9 new Inter-State routes with 7 neighbouring States. OSRTC transported players for National and Inter-National events. Construction of an ISBT (Inter-State Bus Terminus) at Baramunda and 55 new bus stands across 22 districts were in progress. Financially improved, shifting from a loss of INR 1,055 lakh to a profit of INR 152 lakh with eased Covid-19 restrictions.

2. Rail: Railway routes cover 25 districts in the State, excluding 5 districts. In 2021-22, the State had 2,859 km of railway lines, with 97.5% electrified. Railways contribute 0.9% to State GSVA (Gross State Value Added) but 25% to the transport sector GSVA of Odisha. In 2020-21, railways contracted by 13.3% due to COVID-19 but are estimated to grow by 10.5% in 2022-23. The railway route length in the State is about 18 km per thousand sq. km, slightly below the national average of 20 km. Expanding the rail network may increase its contribution to State GSVA and attract investment in the industrial and mineral sectors.

3. Aviation: Air transport was severely affected by COVID-19, contracting 46.3% in 2020-21. However, it rebounded strongly in 2021-22, with a growth of 75.2% and an estimated 58% growth in 2022-23. Its contribution to Odisha's total GSVA is less than one percent. Biju Patnaik Airport in Bhubaneswar, which started international flights in July 2015, saw substantial growth in 2021-22, with a 42% increase in passenger traffic, 42% growth in cargo movement, and 21.2% revenue growth compared to 2020-21. The Airports Authority of India's development plans will further boost its growth and recognition for modern facilities and capacity (Commerce & Transport Department & Government of Odisha, n.d.).

3.6 Access to Infrastructure

3.6.1 Disaggregated Level of Access to Infrastructures and Services

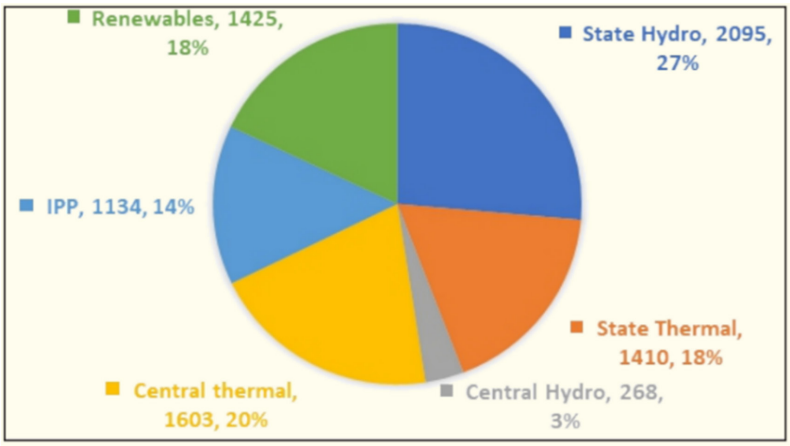
Odisha has achieved significant progress in improving access to infrastructure and services. Although some isolated areas still experience distribution issues, the State has boosted household access to power. There have been initiatives to supply clean drinking water and encourage good hygiene in rural communities. Initiatives have also been put in place to build and improve healthcare facilities. Odisha has been focusing on enhancing school accessibility and infrastructure. To improve communication between various regions, the State has also been trying to improve transportation infrastructure, including highways and public transit networks.

3.6.2 Energy Scenario of the State

In contrast to 8018.3 MW in 2020–21, the State's share of the installed capacity of all power projects—including the proportion of electricity from central and other sources—was 8107.1 MW in 2021–22, representing a **1.1% increase**. The installed capacity of power procurement is given in the figure below.

Figure 26: Installed contracted capacity (MW) (as of 31.03.2022)

Source: 27th Annual Report 2021-2022 by GRIDCO



Renewable Energy Sources

As of 31.03.2022, GRIDCO (Grid Corporation of Odisha) has executed PPAs for a total RE capacity of 2210.15 MW, out of which solar capacity is 1731 MW and non-solar capacity is 479.15 MW, as detailed below;

Table 19: Total contracted capacity of renewable energy sources

Source: 27th Annual Report 2021-2022 by GRIDCO

RE Sources		Contracted Capacity (in MW)
Solar	**Sub-total**	**1731**
Non-solar	SHEP	109.15
	Wind	350
	Biomass	20
	Sub-total	**479.15**
	Total	**2210.15**

Solar commissioned capacity of 985 MW (out of 1731 MW) and non-solar commissioned capacity of 450.65 MW (out of 479.15 MW) totals 1435.65 MW, which is used to reach the stipulated RPO (Renewable Purchase Obligation) objective.

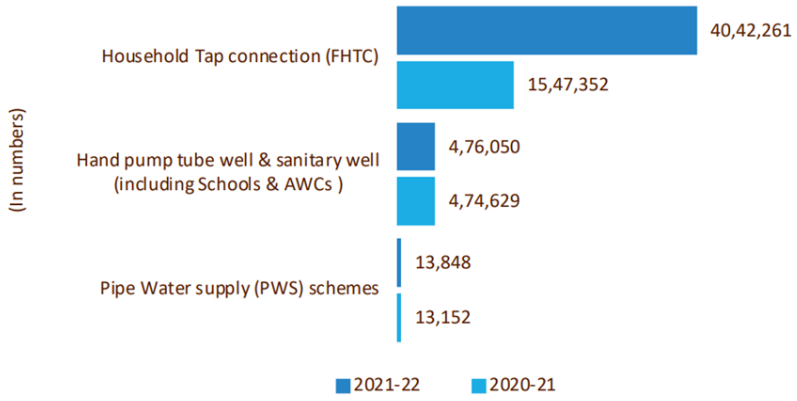
3.6.3 Access to Clean Water and Sanitation

Water Supply

In rural areas, various piped water supply schemes are being implemented, including Rajiv Gandhi drinking water supply programme, NRDWP (renamed as Jal Jivan Mission), BASUDHA, etc. As of 31.3.2022, the State has commissioned 13,848 new PWS (Piped Water Supply) schemes, providing functional household tap connections (FHTC) to 40,42,261 out of 88,57,396 rural households.

Figure 27: Progress in water supply facility in rural Odisha in 2021-22

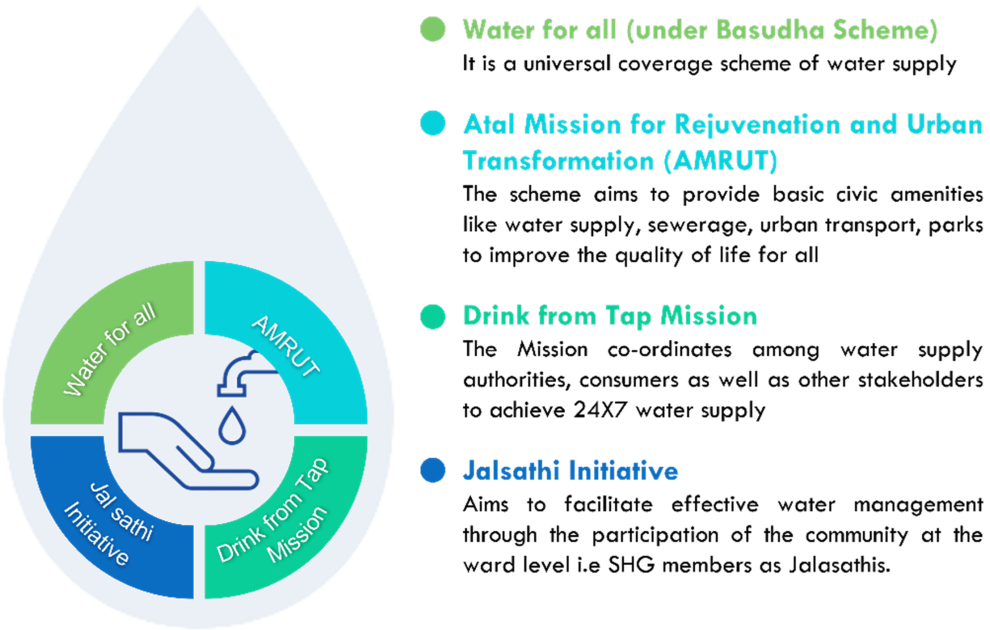
Source: Office of the Engineer in Chief, RWSS, GoO



In urban areas, the State aims for universal coverage with adequate quality drinking water supply, ensuring equitable access for all. In the first phase, the Water Corporation of Odisha (WATCO), a Not-for-Profit company, was established to provide water and wastewater services in Bhubaneswar, Khordha, and Jatni municipal areas. Due to its successful track record, WATCO now serves 29 cities, covering over 60% of the urban population in the State. The prominent schemes for urban water supply by the Government of Odisha are shown in the figure below.

Figure 28: Major schemes for water supply in urban areas

Source: Odisha Economic Survey, 2022-2023

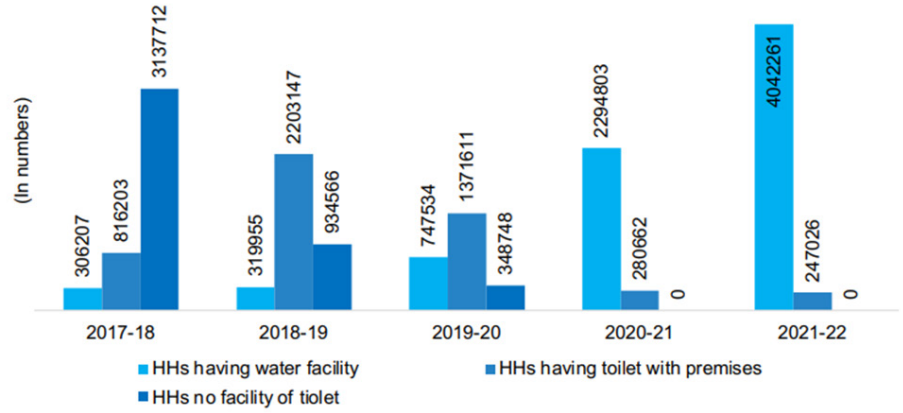


Sanitation

According to the NITI Aayog report, Odisha excelled in SDG 6 (Clean Water and Sanitation). It achieved 100% Open Defecation Free (ODF) status in 2019, with all 30 districts declared ODF. Also, Odisha has been ranked fourth among major states in the Open Defecation Free (ODF) Plus ranking for villages under Swachh Bharat Mission (Grameen). Consequently, the number of households without toilet facilities reached zero in 2020-21. The figure below displays rural sanitation progress in Odisha from 2017-18 to 2021-22.

Figure 29: HHs having water facility and toilet within premises (In N.os)

Source: RWSS (Rural Water Supply & Sanitation Division), GoO



3.6.4 Access to Public/Affordable Amenities

Healthcare

Odisha's public healthcare facilities include 32 District Hospitals, 33 Sub-Divisional Hospitals, 384 CHCs (Community Healthcare Centres), 1379 PHCs (Primary Healthcare Centre), 6688 Sub-centres, 619 Ayurvedic Dispensaries, and 561 Homeopathic Dispensaries (Health_Dept_AR_2016-17A, n.d.). Efforts continue to establish new PHCs / UPHCs (Urban Primary healthcare Centre) and upgrade facilities as per IPHS (Indian Public Health Standards) 2022. INR 8000 lakh (USD 9.7 million) is allocated for upgradation in 2022-23, with special measures to mobilise super specialists to Western Odisha by extending incentives to VIMSAR in Burla (Veer Surendra Sai Institute of Medical Sciences and Research), as in KBK districts (Kalahandi-Balangir-Koraput).

Education

Over 90% of schools are accessible by all-weather roads. The Rashtriya Madhyamik Shiksha Abhiyan (RMSA) aims to provide quality and affordable education to 14-18-year-olds, emphasising relevant skills and life skills. Secondary education is available within a reasonable distance, focusing on marginalised groups. The State performs well in providing mid-day meals, prevalent in nearly 99% of schools, ranking 4th among States on this parameter as per the Economy Survey Report,2020-2021.

3.6.5 Housing Infrastructure

In Odisha, pucca houses are home to 45% of households, and 86 % of them have electricity. An improvement from 80% at the time of NFHS-3 is that 65% of families do not utilise a sanitation facility, which indicates that household members defecate in the open. Rural families (72%) use open defecation far more frequently than urban households (28%). In Odisha, just 10% of homes have a water pipe running into their house, garden, or plot.

Coarse aggregates sourced from rock breaking processes for construction purposes

4. Enabling Environment

4.1 Global Policies and Treaties

In the realm of global sustainability policies and treaties, the dynamics shaping emissions patterns are multifaceted. These encompass several pivotal factors:

"(i) population growth, especially in developing countries,

(ii) increase in floor area per capita, driven by the increase of the size of dwellings while the size of households kept decreasing, especially in developed countries,

(iii) the inefficiency of the newly constructed buildings, especially in developing countries, and the low renovation rates and ambition level in developed countries when existing buildings are renovated,

(iv) the increase in use, number, and size of appliances and equipment, especially ICT and cooling, driven by the growing welfare (income) and

(v) the continued reliance on fossil fuel-based electricity and heat slow decarbonisation of energy supply. These factors taken together are projected to continue driving GHG emissions in the building sector in the future." (Sixth Assessment Report — IPCC, n.d.)

In the pursuit of a more sustainable future, numerous global treaties and policies have been established to address key challenges like resource efficiency and carbon emissions at a global level.Below are global treaties and policies India is a signatory to.

a. Agenda 2030 and the Sustainable Development Goals

India is a signatory to the 2030 Agenda for Sustainable Development, which includes the SDGs. The Indian government has aligned its national development plans with the SDGs. It has been working on various initiatives to achieve the goals related to sustainable cities and communities.

b. Paris Agreement

India is also a signatory to the Paris Agreement and has ratified it. The country has committed to reducing its carbon intensity and increasing the share of non-fossil fuel energy in its energy mix. Various national policies and programs have been initiated to promote renewable energy and reduce greenhouse gas emissions.

c. New Urban Agenda

India participated in the Habitat III conference and endorsed the New Urban Agenda. The Indian government has been working on urban development and smart city initiatives to promote sustainable urbanisation and improve city infrastructure and services.

d. Cities Race to Zero

The Race to Zero is a global campaign to rally leadership and support from businesses, cities, regions, and investors for a healthy, resilient, zero-carbon recovery that prevents future threats, creates decent jobs, and unlocks inclusive, sustainable growth. The Cities Race to Zero is a track of Race to Zero for cities only, where cities are uniting to demonstrate their support for inclusive climate action in line with the goals of the Paris Agreement (Cities Race to Zero - C40 Cities, 2022).

Cities Race to Zero is coordinated by C40 Cities, the Global Covenant of Mayors for Climate & Energy (GCoM), ICLEI – Local Governments for Sustainability (ICLEI), United Cities and Local Governments (UCLG), CDP, the World Wide Fund for Nature (WWF), and the World Resources Institute (WRI) with the aim of rallying urban centres to participate in the Race to Zero initiative. The following Indian cities are part of the campaign (United Nations Framework Convention on Climate Change, n.d.):

1. Achalpur (MH)
2. Ahmednagar (MH)
3. Akola (MH)
4. Ambarnath (MH)
5. Amravati (MH)
6. Aurangabad (MH)
7. Barshi (MH)
8. Beed (MH)
9. Bengaluru (KN)
10. Bhiwandi Nizampur (MH)
11. Bhusawal (MH)
12. Chandrapur (MH)
13. Chennai (TN)
14. Delhi (DH)
15. Dhule (MH)
16. Gangtok (SK)
17. Gondia (MH)
18. Gwalior (MP)
19. Hinginghat (MH)
20. Ichalkaranji (MH)
21. Indore (MP)
22. Jalgaon (MH)
23. Jalna (MH)
24. Kalyan Dombivli (MH)
25. Kochi (KL)
26. Kolhapur (MH)
27. Kolkata (WB)
28. Kulgaon Badlapur (MH)
29. Kupwad (MH)
30. Latur (MH)
31. Malegaon (MH)
32. Mira Bhayander (MH)
33. Miraj (MH)
34. Mumbai (MH)
35. Nagpur (MH)
36. Nanded Waghala (MH)
37. Nadurbar (MH)
38. Nashik (MH)
39. Navi Mumbai (MH)
40. Osmanabad (MH)
41. Panaji (GA)
42. Panvel (MH)
43. Parbhani (MH)
44. Pimpri Chinchwad (MH)
45. Pune (MH)
46. Sangli (MH)
47. Shimla (HP)
48. Solapur (MH)
49. Surat (GJ)
50. Thane (MH)
51. Udaipur (RJ)
52. Udgir (MH)
53. Ulhasnagar (MH)
54. Vasai-Virar (MH)
55. Visakhapatnam (AP)
56. Wardha (MH)
57. Yavatmal (MH)

4.2 Policies Around Resource Efficiency and Circular Economy

a. Strategy on Resource Efficiency

In 2017, the NITI (National Institution for Transforming India) Ayog formulated a "**Strategy on Resource Efficiency**" to propose a comprehensive plan aimed at improving the efficient utilisation of resources within the Indian economy and industry. This strategy focuses on enhancing resource utilisation primarily in the construction and mobility sectors, which have experienced rapid growth, consume substantial materials, and make significant contributions to India's GDP and employment. Initially, the strategy concentrated on abiotic material resources, excluding fossil fuels, and is expected to eventually encompass biotic resources like water and land, as well as other sectors such as agriculture and electronics, and a wider range of materials like plastics and photovoltaics, covering the full spectrum of resources in the country.

b. India-EU Resource Efficiency and Circular Economy Partnership

In 2017, the EU and India jointly declared their ambition to reconcile economic growth with environmental protection. The objective of this joint declaration was to establish an **India-EU Resource Efficiency and Circular Economy Partnership**, which would bring together representatives from both sides, including government officials, businesses (including startups), academic institutions, and research organisations.

c. Draft National Resource Efficiency Policy (NREP)

The Ministry of Environment, Forest and Climate Change (MoEFCC) released a **Draft National Resource Efficiency Policy (NREP)** in 2019. This policy envisions a future characterised by environmentally sustainable and equitable economic growth, resource security, a healthy environment, and the restoration of ecosystems with rich biodiversity. The

policy outlines action plans to be implemented over three years starting from 2019. Its guiding principles include reducing primary resource consumption to sustainable levels, generating higher value with fewer materials through resource-efficient and circular approaches, minimising waste, and promoting employment opportunities and business models that align with environmental protection and restoration goals.

The Draft NREP identifies seven priority sectors for the initial action plans: the automotive sector, plastic packaging sector, building and construction sector, electrical and electronic equipment sector, solar photovoltaic sector, steel sector, and aluminum sector. These sectors are emphasised due to their substantial contribution to India's GDP, accounting for approximately 25% of the country's economic output.

d. C&D Waste Management

The Central Pollution Control Board (CPCB) periodically releases waste management guidelines. As per Rule 3(c) of the Construction and Demolition (C&D) Waste Management Rules (2016), 'construction and demolition waste' comprises materials, debris, and rubble from civil structure activities. Rule 4(4) prevents littering of such waste to avoid traffic and drainage issues. These rules apply to waste from construction, remodeling, repair, or demolition generated by individuals, organisations, or authorities involved. They encompass environmental and waste management compliance, emphasising noise and dust control. These policies are crucial to ensure pre-project compliance with waste management guidelines for any infrastructure endeavor (Central Pollution Control Board, India, 2017).

e. Environmental Considerations and Policy Impacts

The MSME policy addresses a spectrum of environmental aspects encompassing energy efficiency, reduction of GHG emissions, reuse, recycling, energy conservation, minimisation of hazardous substances, protection of local ecosystems, efficient waste management, and resource recovery (Modak 2017).

f. Delhi Declaration

In the **Delhi Declaration** (2023), efforts are made to uncouple economic growth from environmental degradation and promote sustainable consumption and production. Circular economy principles, extended producer responsibility, and resource efficiency are acknowledged as crucial to achieving sustainable development. The declaration recognises the launch of the Resource Efficiency and Circular Economy Industry Coalition (RECEIC) under the Indian presidency and commits to environmentally sound waste management, significant waste reduction by 2030, and the importance of zero waste initiatives.

g. NDC Submission and the Construction Sector

The State of Odisha's Nationally Determined Contributions (NDC) pledges to mitigate climate change mostly rely on the building industry. NDCs are essential plans for reducing greenhouse gas emissions and adapting to the effects of climate change.

Salient features:

1. **Green Building Practices:** Odisha strongly emphasises implementing green building techniques to reduce the construction industry's carbon footprint. This entails encouraging energy-efficient structures, using environmentally friendly building materials, and incorporating renewable energy sources.

2. **Climate-Resilient Infrastructure:** Creating climate-resilient infrastructure that can endure severe weather events and shifting climatic circumstances is prioritised in NDC proposals. This is essential for a state vulnerable to storms and rising sea levels.

3. **Sustainable Urban Planning:** To control urban expansion, improve public transit, and reduce the environmental effects of urban development, sustainable urban planning is integrated.

4. **Afforestation and Reforestation:** NDC submissions discuss reforestation and afforestation programmes to reduce emissions from the building industry. Trees help remove carbon dioxide from the atmosphere by serving as carbon sinks.

5. **Waste Management:** To reduce waste production and encourage recycling and material reuse, the NDC for Odisha strongly emphasises efficient waste management techniques in the construction industry.

Odisha is committed to assisting India's overall climate goals and building a sustainable, climate-resilient future by integrating the construction industry with these climate measures.

4.3 Legislative and Regulatory Instruments Pertaining to Odisha's Building and Construction Industry

In the context of Odisha, the construction industry is subject to a framework of legislative and regulatory instruments that influence its operations and sustainability practices. These instruments aim to guide construction activities while also fostering environmentally responsible approaches.

a. Odisha Development Authorities Rules (Planning and Building Standards), 2020

The ODA (Planning and Building Standards) 2020 serves as a foundational document dictating the state's construction norms. While primarily focused on the physical aspects of construction, these guidelines may encompass sustainable features such as energy-efficient designs, waste management protocols, and water conservation strategies.

Provisions for Building Materials

The structural design of various building components, including foundation, masonry, timber, plain concrete, reinforced concrete, prestressed concrete, and structural steel, must adhere to the guidelines set forth in the National Building Code of India. This involves considering relevant Indian Standards provided by the Bureau of Indian Standards, ensuring general structural safety, and protection against cyclones, wind, storms, earthquakes, and landslide hazards. All construction materials and workmanship must meet high-quality standards in line with the accepted norms of the Public Works Department and Indian standard specifications and codes outlined in the Building Materials and Construction Practices and Safety section of the National Building Code of India. Building materials approved by the Bureau of Indian Standards (B.I.S.) or other relevant regulatory bodies are considered part of the sanctioned building materials and technologies outlined in the rules.

The reference standards are: "Energy Conservation Building Code, 2007 and the National Building Code of India are the primary reference documents/standards for lighting levels, HVAC, comfort levels, natural ventilation, pump and motor efficiencies, transformer efficiencies, and other building materials and system performance criteria."

Provisions for Green Buildings

The applicability of Green Building Provisions is based on plot size for residential and non-residential use. These include mandates for water conservation and management norms, solar energy utilisation, energy efficiency, and waste management. This regulatory instrument encourages the adoption of Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environmental Design (LEED), Indian Green Building Council (IGBC), and Energy Conservation Building Code (ECBC) rating certification for new and existing buildings. The incentive for the same will be based on applicable State Government policy as applicable from time to time (Housing and Urban Development Department, Odisha, 2020).

b. Odisha Renewable Energy Policy 2022

The Odisha Renewable Energy Policy stands as a driving force in promoting the adoption of renewable energy sources, such as solar and wind power, within the state. While not exclusively tied to construction, this policy could potentially influence building design by encouraging the integration of solar panels and other renewable technologies.

c. State Action Plan on Climate Change (SAPCC)

The State Action Plan on Climate Change outlines the strategic steps to tackle climate change impacts across sectors, including construction and urban development. It may entail measures to ensure energy-efficient building practices,

incorporation of green infrastructure, and sustainable urban planning. The studies conducted to inventorise sectoral GHG emissions indicate that the state has emissions of 98.525 megatons of CO_2 equivalent[4]. It is also noted that power-intensive sectors, including cement, aluminium, and steel, have a large presence in the State because of its strong mineral base.

The Odisha State Climate Change Action Plan (2018-23) has listed recommendations for reducing Odisha's carbon footprint. Among these are:

- The promotion of green buildings in residential and commercial spaces. This could be done by operationalising the Energy Conservation Building Code (ECBC), which was rolled out by the Bureau of Energy Efficiency (BEE). The ECBC and the Eco-Niwas Samhita, a code specifically drafted for residential buildings.
- The document also makes mention of a higher floor area ratio (FAR) for green buildings as a potential policy incentive.

The Odisha SAPCC does not specifically mention sustainable or green building materials. Most of its recommendations specific to the building and construction industry are based on how to reduce the operational energy of buildings (Forest & Environment Department, Government of Odisha, 2018).

It does, however, touch upon the need to amend and update current building bye-laws in accordance with climate change and disaster risk reduction factors.

d. Municipal Building Bye-Laws

Local municipalities in Odisha often tailor bye-laws to align with state regulations while catering to regional nuances. These regulations could encompass sustainable construction practices, rainwater harvesting strategies, waste management protocols, and the preservation of green spaces.

The government mandates no established BIM standards or rules, and although awareness of BIM has increased, its full potential has not yet been explored.

e. Laws Concerning Labourers and Contractors

Key employment laws governing labour conditions are as follows:

- *Industrial Disputes Act, 1947:* Regulates industrial dispute resolution, the legality of strikes, lay-offs, and retrenchment. Applies to workers, excluding managerial or supervisory roles.
- *Shops and Commercial Establishments Acts:* Enacted by state governments, these laws cover working hours, salaries, holidays, leave entitlements, and termination. Some states exclude managerial employees.
- *Minimum Wages Act, 1948:* Sets minimum wage rates employers must adhere to.
- *Inter-State Migrant Workmen Act, 1979:* Governs conditions for migrant workers from other states.
- Building and Other Construction Workers Act, 1996: Applies to businesses employing 10+ construction workers in a year, simplifying registration. Regulates construction workers' conditions.
- *Contract Labour Act, 1970:* Regulates and abolishes contract labour. This applies if a major employer hires 20+ contractual labourers.
- *Factories Act, 1948:* Prevents employment of those under 14 in factories, mandates fitness certificates for 15-18 year-olds, and requires safety inspectors in factories with over 1,000 employees.

These laws, alongside the Labour Codes, significantly influence labour and contractor employment conditions (Laware Associates, 2023)

4 98.525 megatons of CO2-equivalent is equivalent to the emissions of over 20 million cars driven around the Earth's equator more than 300,000 times (OpenAI, 2023).

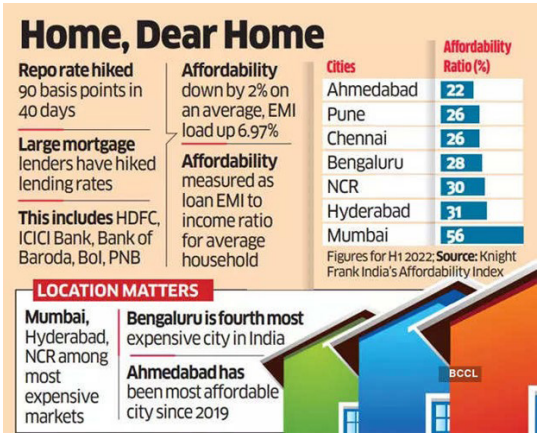
4.4 Policies and Regulations for Affordable Housing

According to the Government of India, Affordable Housing refers to housing units that are affordable by that section of society whose income is below the median household income. In India, affordable housing is provided for low-income, middle-income, and economically weaker sections with considerably low levels of income (urban areas).

The Government of India's Affordable Housing Project entails utilising 60% of FAR/FSI for dwelling units with a Carpet Area not exceeding 60 sqm. Additionally, 35% of units (21-27 sqm) are reserved for the EWS category. Launched in June 2015, this initiative targets lower/middle-income households. Affordable housing units qualify for a lower 1% GST rate, offering relief to buyers. In metropolitan cities, units ≤₹45 lakh, ≤60 sqm, are eligible. In non-metros, ≤₹45 lakh, ≤90 sqm.

Figure 31: Affordability index of major cities in India

Source: Economic Times, July 2022



Access to affordable housing is a fundamental right, and the Government of Odisha recognises the importance of addressing the housing needs of low-income groups and promoting sustainable disaster reconstruction. Through a range of government and donor-funded housing schemes, Odisha is actively working towards providing secure and affordable housing options to vulnerable communities while also focusing on building resilience to natural disasters. This section offers a comprehensive overview of the significant housing schemes in Odisha, including Jaga Mission, Biju Pucca Ghar Yojana, Pradhan Mantri Awas Yojana (PMAY-U and PMAY-G), Odisha Urban Housing Mission (OUHM). By examining the objectives, implementation strategies, outcomes, and donor involvement, we can gain a deeper understanding of the transformative impact of these schemes on the lives of low-income groups and the reconstruction efforts in the state.

a. National Scheme for Affordable Housing

Pradhan Mantri Awas Yojana (PMAY-U and PMAY-G)

Pradhan Mantri Awas Yojana (PMAY) is a flagship program of the Government of India that aims to provide affordable housing solutions for both urban (PMAY-U) and rural (PMAY-G) areas. Implemented with significant momentum in Odisha, PMAY strives to achieve the "Housing for All" vision by 2022. PMAY-U addresses urban housing needs, particularly for economically weaker sections, urban poor, and slum dwellers. The scheme provides financial assistance for constructing, purchasing, or renovating houses and encourages the use of eco-friendly and disaster-resistant technologies. PMAY-G caters to the marginalised, aiming to offer them pucca homes and necessary amenities.

b. State-driven Schemes for Affordable Housing

i. Jaga Mission: Transforming Slum Redevelopment and Urban Development

Jaga Mission is an innovative initiative launched by the Government of Odisha to address the housing needs of slum dwellers in urban areas. The mission's primary objective is to provide land rights and secure tenure to slum dwellers, enabling them to access credit and government services and construct pucca houses. The mission takes a participatory approach, involving slum dwellers in the planning and implementation. It aims to transform slums into sustainable urban settlements by providing basic amenities and infrastructure, thereby improving the living conditions and overall well-being of slum dwellers.

Tapovan slum near Khandagiri, Odisha

The impact of the Jaga Mission can be seen through its achievements. Slum dwellers have been provided with property rights certificates under the scheme, ensuring their security of tenure and access to housing finance. The mission has resulted in constructing pucca houses for slum dwellers, providing them with safe and dignified housing. Providing basic amenities such as water supply, sanitation facilities, and electricity has significantly improved the quality of life for beneficiaries. By involving slum dwellers in decision-making, Jaga Mission has empowered them and created a sense of ownership and community pride.

ii. Odisha Urban Housing Mission (OUHM): Enhancing Urban Housing Infrastructure

Odisha Urban Housing Mission is a state-level initiative aimed at enhancing housing conditions in urban areas, with a specific focus on slum redevelopment, affordable housing for the urban poor, and the provision of basic amenities in urban settlements. OUHM emphasises creating sustainable, inclusive, and resilient urban housing infrastructure. The mission aims to provide safe and affordable housing options to urban residents, especially those belonging to economically weaker sections. It also focuses on improving the quality of life by providing basic amenities such as water supply, sanitation, electricity, and solid waste management.

iii. Biju Pucca Ghar Yojana (BPGY)

Biju Pucca Ghar Yojana is a state-funded flagship program launched in 2014-15, replacing the previous "Mo-Kudia Yojana." The objective is to convert all Kutcha houses into pucca houses. It comprises two components: BPGY (Normal) and BPGY (Special). Under the standard component, expenditures such as incentives for beneficiaries completing homes early, training of officials, and preparation of IEC material are covered. The particular segment caters to rural households affected by natural or man-made calamities, river or sea inundation, beneficiaries of forest-dwelling rights, those affected by occupational diseases, and impoverished households not selected under other housing schemes.

iv. Pucca Ghar Yojana (Mining) (PGY-M)

Implemented in 691 mining-affected villages across eight districts in Odisha, the Pucca Ghar Yojana (Mining) provides pucca houses to kutcha households. The scheme is funded by the Odisha Mineral Bearing Areas Development Corporation (OMBADC) and implemented by the Panchayati Raj & Drinking Water Department. Its primary objective is to ensure that households affected by mining activities have access to safe and permanent housing.

v. Nirman Shramik Pucca Ghar Yojana (NSPGY)

The Nirman Shramik Pucca Ghar Yojana aims to provide housing assistance to building and construction workers registered under the Odisha Building and Other Construction Workers Welfare Board. Eligible workers with a minimum of one year of valid registration under the Building and Other Construction Workers (RE&CS) Act can avail of this scheme. The funding comes from the Odisha Building and Other Construction Workers Welfare Board, and the implementation is carried out by the Panchayati Raj & Drinking Water Department. This scheme's unit assistance and installment pattern are the same as those under Biju Pucca Ghar Yojana.

vi. Mukhya Mantri Karma Tatpara Abhiyan (MUKTA)

MUKTA's vision is to alleviate unemployment, inequality, and poverty in urban areas and build sustainable community resilience through an integrated urban public works programme. The scheme will be implemented by the Housing & Urban Development Department (H&UDD) as a nodal department across all the ULBs of Odisha. The State Urban Development Authority will act as a State Level Nodal Agency. The core objective of the scheme is to create decent wage employment opportunities in urban areas and ensure sustainable livelihoods for the urban poor, including vulnerable groups like migrant labourers, women, transgenders, and persons with disabilities, thereby enhancing human capabilities. The scheme is also focused on ensuring the creation and maintenance of inclusive, sustainable, climate-resilient community assets, thereby improving the quality of life for the urban citizens.

vii. Mission Shakti

"Mission Shakti" is the self-help mission for empowering women by promoting Women Self Help Groups (WSHGs) to take up various socio-economic activities. Mission Shakti aims to empower women through gainful activities by providing credit and market linkage. Empowerment of women through WSHGs under Mission Shakti is the Government's flagship program. It envisages that over a period of time more & more women would be part of a WSHG.

A community water tank

The mission's major focus is institutionalising Women's Self-Help Groups (WSHGs), with federations established at the Gram Panchayat, block, and district levels. Capacity-building for Community Based Organisations, from SHGs to Federations, is a priority. Efforts are aimed at strengthening livelihoods through aggregation for sustainability and facilitating market linkages for SHG products statewide. Raising awareness about social entitlements for women and promoting inter-agency collaboration for livelihood promotion are also emphasised. Additionally, formal financial institution linkages are actively pursued for WSHGs, emphasising practices like regular meetings, credit, thrifts, internal lending, repayment, and financial literacy programs to ensure financial inclusion.

c. Collaborative Schemes

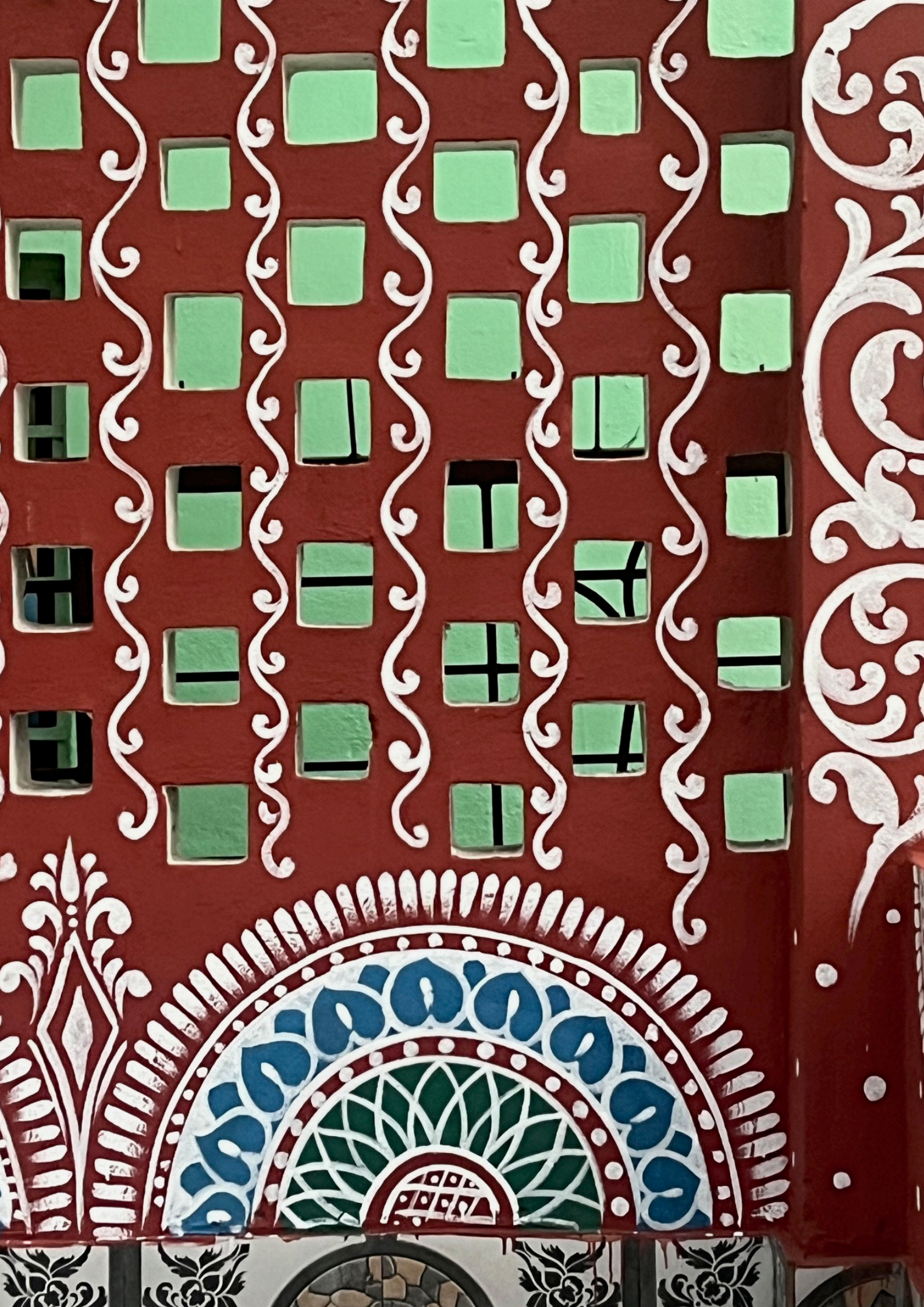
Donor-Funded Housing Schemes: Collaborative Efforts for Sustainable Development

In addition to the government-led initiatives, Odisha has received substantial support from donor agencies and development partners in implementing housing schemes for low-income groups and disaster reconstruction. These collaborative efforts aim to address the specific needs of vulnerable communities and enhance resilience in the face of natural disasters. Donor-funded projects have played a crucial role in constructing resilient houses, restoring critical infrastructure, and promoting livelihood in disaster-affected areas.

Organisations such as the United Nations Development Programme (UNDP), World Bank, National Bank for Agriculture and Rural Development (NABARD), and other international and national agencies have actively supported housing projects in Odisha. Their contributions have significantly contributed to realising the state's vision of sustainable and inclusive development. For example, the UNDP's support in disaster reconstruction efforts has led to the construction of disaster-resilient houses, restoration of community infrastructure, and capacity building of local communities.

In conclusion, Odisha's government and donor-funded housing schemes showcase the state's commitment to social welfare, sustainable development, and inclusive growth. Initiatives such as JAGA Mission, Biju Pucca Ghar Yojana, PMAY-U, PMAY-G, and OUHM have transformed the lives of low-income groups and marginalised communities by providing secure land rights, affordable housing options, and basic amenities. These schemes have improved the living conditions of beneficiaries and empowered them by promoting inclusivity and participation. Collaborative efforts with donor agencies have also strengthened resilience, promoted sustainable development, and enhanced livelihood opportunities for disaster-affected communities. The government's ongoing efforts and the support from donor agencies demonstrate the collective determination to ensure safe, dignified housing for all and build a resilient and prosperous Odisha.

Through the Panchayati Raj & Drinking Water Department, the Government of Odisha has implemented several schemes to provide pucca houses to rural households residing in kutcha houses or who are houseless. These initiatives aim to uplift the living standards of vulnerable communities, promote inclusive growth, and ensure access to safe and permanent housing. In this article, we will explore four significant housing schemes: Pradhan Mantri Awaas Yojana (Grameen), Biju Pucca Ghar Yojana, Pucca Ghar Yojana (Mining), and Nirman Shramik Pucca Ghar Yojana.



4.5 Inclusive Design

4.5.1 Inclusive Design for Population with Disability

According to the 2011 Census of India, approximately 2.21% of the total population, which amounted to 121 crore individuals, were identified as persons with disabilities. This group comprised around 2.68 crore people, with 31% residing in urban areas. Notably, within this population, disabilities intersect with factors such as gender, age, class, caste, religion, and sexuality, amplifying the challenges faced by individuals with disabilities in urban settings. Women and children with disabilities experience heightened exclusion (Vidhi Centre for Legal Policy, 2023).

a. Legal Framework and Disability Rights

The Constitution of India at the national level ensures the fundamental rights of persons with disabilities, guaranteeing their right to equality, freedom, and a dignified life, including the right to accessibility. This rights-based approach is further embodied in the Rights of Persons with Disabilities Act, 2016 (RPWDA). Unlike its predecessor, the RPWDA broadens its focus beyond detection, prevention, and rehabilitation, aligning India with its obligations under the United Nations Convention on the Rights of Persons with Disabilities. This Act places the responsibility on the appropriate government to uphold the rights and entitlements enshrined within it (Ibid).

The Urban and Regional Development Plans Formulation and Implementation Guidelines (URDPFI), 2014, outline the methodology for crafting master plans that cater to the socio-economic needs of residents. They emphasise the necessity for barrier-free urban spaces and inclusive, participatory planning processes.

b. Accessibility Standards for the Built Environment

The RPWDA mandated the Harmonised Guidelines and Space Standards for Barrier-Free Built Environment for Persons with Disabilities and Elderly Persons, 2016, which were updated in 2021. Developed by the MOHUA, these guidelines establish accessibility standards for various components of the built environment, encompassing interior and exterior elements, toilets, stairs, lifts, corridors, parking facilities, and more. Importantly, these guidelines are legally binding and extend to all public buildings, irrespective of whether they are established by government or private entities. Local implementation of the Harmonised Guidelines is contingent on their integration into the building bye-laws set by municipal bodies (Ibid).

In the context of residential buildings, the National Building Code emphasises the essential role of accessibility and universal design for creating barrier-free environments, particularly for individuals with disabilities and the elderly. However, the practical implementation of these principles often falls short within many residential apartments and complexes. Builders and promoters are responsible for ensuring accessibility features such as ground-floor housing, designated parking spaces, and accessible shared amenities like pools and gyms. Subsequently, after the handover of the premises, the apartment association assumes the duty of providing reasonable accommodations to foster an inclusive living environment (Karpagam, 2022).

Section 46 of the ODA (Planning and Building Standards) Rules, 2020, focuses on ensuring inclusive access for individuals with physical challenges, the elderly, and children. The regulation requires proprietors of publicly-utilised structures, encompassing educational, institutional, assembly, commercial, business, and mercantile buildings, as well as housing projects situated on plots exceeding 2000 square meters (excluding private residential buildings), to integrate provisions in line with the 'Handbook on Barrier-Free and Accessibility, 2014' guidelines. These guidelines, developed by the Central Public Works Department (CPWD) under the Ministry of Urban Development, Government of India, serve as a comprehensive reference for promoting universal access. Additionally, it is crucial for these entities to adhere to the specifications delineated in Annexure-VIII, further bolstering the commitment to creating inclusive environments.

4.6 Planning for Built Environment Resilience

4.6.1 Planning for Disaster Resilience

Section 23 of the Disaster Management Act 2005 states that each state must have a comprehensive disaster management plan. This plan outlines the scope of disaster management activities and emphasises the need for collaboration during its preparation.

a. Key Institutions for Disaster Management in the State

In the state, several institutions are responsible for managing disasters. These include the State Disaster Management Authority (SDMA), the Revenue & Disaster Management Department, the Odisha State Disaster Management Authority (OSDMA), and the Office of the Special Relief Commissioner. These institutions oversee various phases of disaster management. Additionally, multiple entities, such as state government departments, district administrations, UN agencies, technical institutions, local government bodies, communities, and NGOs, contribute to and are impacted by the State Disaster Management Plan (SDMP).

b. Integration of Targets and Frameworks

Several guiding frameworks and targets influence the State Disaster Management Plan. These include the specific disaster-related goals of the Sustainable Development Goals 2030, the short and long-term objectives outlined in the Odisha Vision Document 2036, and the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030. Moreover, the 10-point agenda for disaster risk reduction set forth by the Honourable Prime Minister has also been taken into account during the planning process.

c. Unique Vulnerabilities of Odisha

The geographic and climatic conditions of Odisha expose it to various natural disasters. Due to its proximity to the Bay of Bengal, the state's 480 km coastline is particularly susceptible to cyclones and storm surges. Despite constituting only 17% of the east coast, Odisha experiences nearly 35% of cyclonic and severe cyclonic storms along with associated surges. Inland, the Mahanadi River and its tributaries pose a significant risk of severe floods. Moreover, the state's 10 major river systems lead to recurrent floods. Flash floods and landslides are also potential threats in the region.

Based on recent categorisation, Odisha falls within seismic Zones II and III, indicating low to moderate earthquake risk. However, even in these zones, protective measures are crucial. The housing landscape comprises Category A (clay and stone walls) and Category B (burned brick walls) buildings. Despite moderate hazard levels, Category A housing faces the risk of "destruction" damage, including partial collapses, during an earthquake of Intensity VII. Similarly, Category B housing may experience various degrees of cracking, similar to historical events. This highlights the need to implement earthquake protection measures in Intensity VII zones.

Residential structure with G+4 stories completed by BDA, Adjacent to N.H-16, Kalinga Nagar Zone K-9 (B)

5. The Built Environment and Housing Sector

The Human Rights Measurement Initiative finds that India is doing 60.9% of what should be possible at its income level for the right to housing (*India Far from Meeting Its Potential in Economic and Social Rights*, 2020), indicating a major scope of improvement and resource management [1]. In the urban areas of the country, the last official estimate of the requirement of urban housing indicated the need for 18.78 million units (GoI, 2012) with 96% of the need concentrated in the Lower Income Group (LIG) and the Economically Weaker Section (EWS). The Census of India categorises 'Urban' based on two criteria.

Firstly, the state government assigns a municipal status, such as a corporation, municipal council, notified town area committee, nagar panchayat, etc., to a settlement referred to as a statutory or municipal town in the census definition of urban areas.

Secondly, a territory that doesn't have an urban civic status can be declared urban if it meets specific demographic and economic standards, such as a population of more than 5,000, a density of 400 persons per square kilometer, and a 75% male workforce in the non-agricultural sector.

5.1 Building Stock and Housing Units

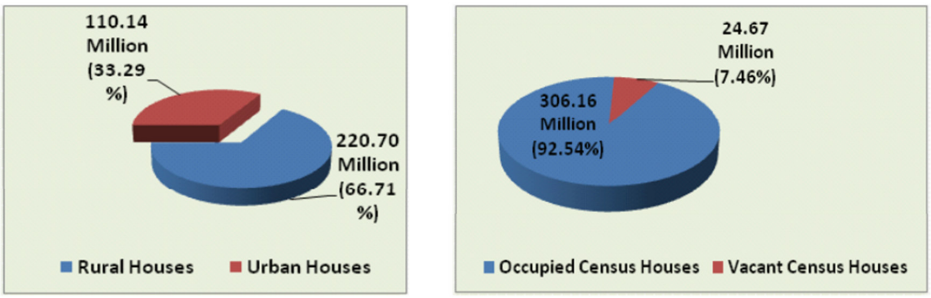
As per the 2011 census, the total number of houses in India was 330.84 million, which includes 306.16 million occupied and 24.67 million vacant houses. The number of houses in rural areas was 220.70 million, with 207.12 million occupied houses and 13.58 million vacant houses; in urban areas, the number was 110.14 million, including 99.05 million occupied and 11.09 vacant houses.

Table 21: Total number of census houses: rural & urban 2011

Area	Total Number of Census Houses	Distribution of Census Houses	
		Occupied Census Houses	Vacant Census Houses
Rural	220.70	207.12	13.58
Urban	110.14	99.04	11.09
India	330.84	306.16	24.67

Figure 32: Total number of Census Houses, 2011 - Rural and Urban; Occupied and Vacant

Source: Census of India, 2011



Pucca and Kutcha Houses

According to the Government of Odisha, a 'pucca' house is one with the following characteristics:

- **Material**- The structure must have a foundation, wall, and roof of permanent material.
- **Wall material**- Fly ash bricks, burnt bricks, stones (packed with lime or cement), cement concrete.
- **Roof material**- Tiles, GCI (Galvanized Corrugated Iron) sheet, asbestos cement sheet, RBC (Reinforced Brick Concrete), and Reinforced Cement Concrete (RCC)
- **Lifetime**- The expected life of a building is expected to be a minimum of 30 years.

TThe document circulated by the Government of Odisha on the Biju Pucca Ghar Yojana Scheme clarifies that the above definition pertains explicitly to the verification process for existing households. However, it has also been explained that any houses constructed in the future under the Biju Pucca Ghar Yojana scheme will be built using Reinforced Cement Concrete (RCC) or any other material that possesses equivalent strength, as approved by the PR & DW Department.

A 'kutcha' house is a habitable unit in which walls and roofs are made of materials such as unburnt bricks, bamboo, mud, grass, reeds, thatch, loosely packed stones, and materials not mentioned above. Materials that aren't considered durable due to inappropriate application of techniques cannot withstand wear and tear.

The concepts of 'pucca' and 'kutcha' housing are intricately tied to construction methods and materials, influencing public perception of alternative building options. To promote eco-friendly alternatives, government-led advocacy and policy shifts are crucial. Current definitions, influenced by traditional norms, impact construction choices and socioeconomic views on housing. The term 'pucca' typically refers to well-built structures like RCC buildings, symbolising stability and social status. This perception hinders acceptance of alternative materials. A broader outlook is needed, necessitating changes in official standards and public perspectives for embracing sustainable housing practices.

Table 22: Distribution of census houses (in percentage) used as residence by their type of structure

Source: Census of India, 2011

Area	Pucca	Semi-Pucca	All Kutcha
Rural	55.40	27.6	17.0
Urban	91.70	6.20	2.10
India	**66.10**	**21.30**	**12.60**

Table 23: Households by their habitable condition of census houses occupied

Source: Census of India, 2011

Area	Total no. of Households	Distribution of Households by their Habitable Condition of Census Houses Occupied		
		Good	**Liveable**	**Dilapidated**
Rural	166.16	76.36 (46%)	78.97 (48%)	10.82 (6%)
Urban	53.69	34.45 (64%)	17.31 (32%)	1.93 (4%)
India	**191.96**	**96.45 (50%)**	**84.96 (44%)**	**10.55 (6%)**

Table 24: Distribution residences as per the habitable condition

Source: Census of India, 2011

Number of Residences as per their condition (Census Houses)				
Area	**Total**	**Good**	**Liveable**	**Dilapidated**
Rural	79.22	20.20 (25%)	52.03 (66%)	6.99 (9%)
Urban	14.82	7.66 (52%)	6.31 (43%)	0.86 (5%)
Odisha	94.04	27.86 (30%)	58.34 (62%)	7.85 (8%)

Table 25: Distribution of residences as per the habitable condition in the urban area of Bhubaneswar

Source: Census of India, 2011

Number of Residences as per their condition in the Urban area of Bhubaneswar (Census Houses)				
Area	**Total**	**Good**	**Liveable**	**Dilapidated**
Urban	1.98	1.19 (60%)	0.69 (35%)	0.09 (5%)

5.1.1 Housing Trends in Odisha and Bhubaneswar

The Odisha Urban Housing Mission oversees the building and allocating affordable housing projects in Odisha (AWAAS). In Bhubaneswar, the ULB in charge is the Bhubaneswar Development Authority. The government established the Odisha Urban Housing Mission (AWAAS) to assess the need for a state-level institutional organisation focused only on urban housing.

The current scenario indicates a major gap between the housing supply and the requirement of around 52,588 units in the case of the Economically Weaker Sections (EWS) and Low-income group (LIG). Table 2 illustrates the overall housing shortfall in the BMC region as well as the number of dwellings covered by different government programmes such as Beneficiary-Led Construction (BLC), Affordable Housing in Partnership (AHP), In-Situ Slum Redevelopment (ISSR), and others. Whereas about 23.45 percent of the housing shortfall has been met thus far, 76.55 percent of the total housing requirement remains to be addressed to alleviate the area's housing shortage (PMAY-Bhubaneswar, 2023).

Figure 33: Bhubhaneswar SMART city area-based development plan

Source: Bhubaneswar SMART City Development Plan, 2016

According to data from the Odisha Urban Housing Mission, the Housing for All Plan of Action (HFAPoA) 2019 outlines a housing demand of 5.02 lakhs in the state of Odisha. Out of this demand, 1.89 lakh houses have been approved for construction, and orders have been issued for 1.63 lakh houses. Considering the rapid urbanisation in the city of Bhubaneswar, it is projected that the housing demand in the city will reach 4.3 lakhs by the year 2030.

5.2 Financial Expenditure Under PMAY-U in Bhubaneswar

Table 26: Bhubaneswar- financial investment and progress for affordable housing

Source: PMAY-U

Financial Progress in Cr.			Physical Progress in No.s		
Investment	Central Assistance	Sanctioned Central Assistance Released	Houses Sanctioned	Houses Grounded*	Houses Completed*
2,692.31	474.32	212.72	30,644	15,935	6,164

Table 27: Odisha- financial investment and progress for affordable housing

Source: PMAY-U

	Financial Progress in Cr.			Physical Progress in No.s		
Project Proposal Considered	Investment	Central Assistance	Sanctioned Central Assistance Released	Houses Sanctioned	Houses Grounded*	Houses Completed*
976	9,873.96	3,369.37	2,108.86	2,13,845	1,71,770	1,28,263

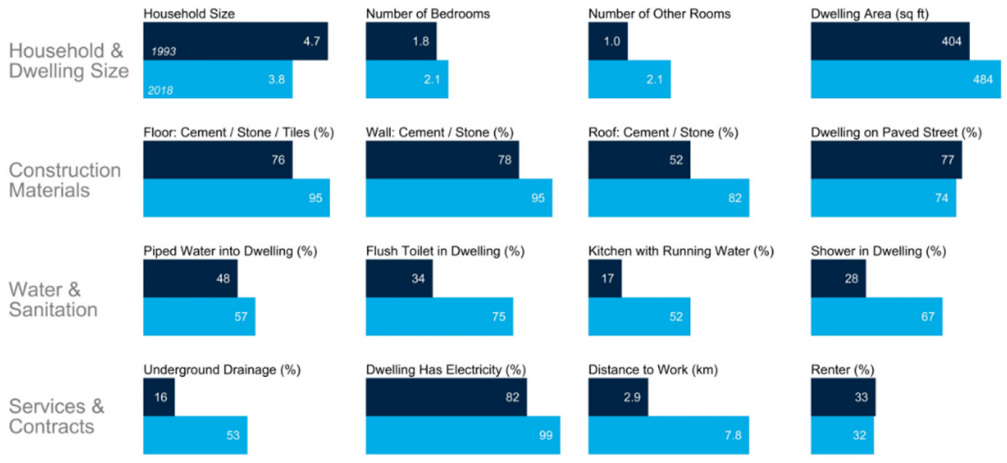
Factors that drive the demand for housing:

Various factors influence the demand for housing. Some of them have been listed below:

- Demographic Shift
- Population Growth
- Economic Growth
- Household Composition
- Government Policies
- Cultural and Lifestyle factors
- Interest rates of housing loans

Figure 34: Housing amenities and characteristics in urban India 1993-2018

Source: National sample Survey (NSS) Rounds 49 and 76, 2018



India's population has experienced rapid growth, making it the most populous country globally, surpassing China (UN DESA Policy Brief No. 153, 2023). As a result, there has been a significant increase in the demand for housing, particularly affordable housing. During the period from 2010 to 2021, there has been a noticeable decrease of 8.6% in household size, with the average household size declining from 4.86 to 4.44 (National Sample Survey, Government of India, 2021). This shift towards smaller household sizes has led to fragmented and individualised living patterns, creating a need for affordable and compact housing options, particularly for several communities.

Odisha, for instance, has an average household size of 3.46, well below the national average (National Sample Survey, Government of India, 2021). In response to these demographic changes and the growing demand for housing, Bhubaneswar is adapting its development plans. The city's new development strategy focuses on accommodating the shifting population and demographic trends, leading to changes in urban institutions and policies. Notably, the government has relaxed the Floor Area Ratio for constructing affordable housing, setting it at 7 (as informed by OUHM) to meet the increased demand. This move aims to address the housing needs of the expanding population while promoting affordable and accessible housing options in the city.

The state has also been active in its slum upgradation programme by launching schemes like JAGA Mission, which focuses on providing land titling rights to the citizens for land tenure and security. This step adds to the citizens' confidence and contributes to the ease of accessibility of housing.

5.2.1 Housing Delivery Systems and Current Situation in India and Odisha

IIn recent decades, there have been numerous cases where government-subsidised low-income housing units built under various national housing schemes (such as PMAY, JnNURM, and RAY) have remained unoccupied or unallocated for extended periods. This issue is evident from the high numbers depicted in the map, representing the gaps in the JNNURM and RAY housing projects. The central government has attempted to address this problem by introducing the Affordable Rental Housing Complexes (ARHC) scheme to utilise vacant housing units. However, according to the latest data from the Ministry of Housing and Urban Affairs (MoHUA), in 2023, only 6.7% of the vacant housing has been converted to ARHC.

In 2019, the Housing and Urban Development Department of Odisha signed agreements with organisations such as the e-gov Foundation, Janagraha Centre for Citizenship and Democracy, and Indian Heritage Cities Network Foundation to enhance urban services in the state; the services encompass housing, neighborhood maintenance, urban safety and security, transit-oriented development, and other basic amenities.

Despite several beneficiary surveys and the finalisation of eligible beneficiary lists, the physical allotment of units could be faster. This situation creates a precarious scenario where land is available, and houses are constructed; however, delivering the finished products to the intended beneficiaries still needs completion in due period. The Odisha government recently signed an MoU with the central government to convert these unallocated/vacant housing stocks into rental housing under the Affordable Rental Housing Complexes (ARHCs) scheme, which is a part of the ongoing Pradhan Mantri Awas Yojana (Urban) (PMAY-U) mission. However, this move has caused confusion regarding utilising previously committed housing stocks, leading to overlapping commitments and promises regarding supposedly "vacant" houses.

A study conducted by the Indian Council Research for International Economic Relations in 2022 examined the Housing Delivery System in India. It highlighted the role of policy guideline changes in causing delays in housing allotment. The study emphasised that India's housing interventions have had limited success due to frequent policy changes and a lack of interconnectedness. Introducing new policies led to changes in eligibility cut-off dates and beneficiary contribution requirements for rehabilitation. The revised rehabilitation policy in 2015 changed the cut-off date from the previous policy, making reha established before January 1, 2006, eligible for rehabilitation.

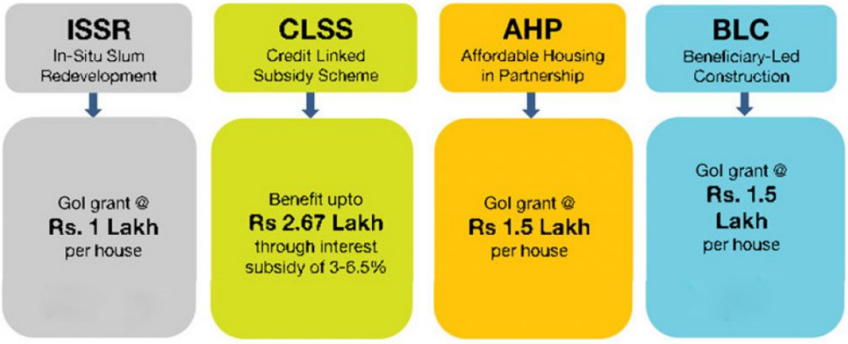
Additionally, the beneficiary contribution for rehabilitation increased from INR 60,000 under the 2010 policy to INR 1,12,000 under the new policy. These policy changes affected the housing allotment process in various ways. The altered cut-off date allowed basti residents who were previously ineligible to become eligible for rehabilitation, necessitating additional surveys to determine the number of eligible residents under the new policies. This procedural complexity caused delays, and previously qualified individuals found themselves caught in the process.

Furthermore, the increased beneficiary contribution exacerbated the difficulties faced by residents. The study also revealed significant figures related to housing vacancies. Delayed allotment or long waiting times accounted for 23% of vacant housing, court orders/stays/rulings for 19%, issues with the beneficiary list for 12%, and non-receipt of project completion certificates for 6%. These findings highlight that the processes involved in housing construction, completion formalities, and the allocation of dwelling units contribute significantly to the high vacancy rates. Overall, it can be analysed that while housing debates often focus on production, demand, and supply, there is a lack of scholarly attention given to the timely delivery of completed housing units to intended beneficiaries. The present study aims to understand the reasons behind the delays in delivering dwelling units to the intended beneficiaries.

Pradhan Mantri Awaas Yojana, the current initiative of providing housing to the citizens, has the following method of delivery:

Figure 35: PMAY (U)- housing delivery method

Source: pmay-urban.gov.in



As of 30th March 2022, the CLSS was discontinued as a valid Affordable Housing sanctioning process. However, on 17th August 2022, the Government of India issued a memo stating that the scheme would be extended until 31st December 2024. During this period, no new houses would be sanctioned under the scheme. Instead, the focus would be completing the houses sanctioned before 30th March 2022.

Installment Pattern for Housing Schemes in Odisha:

All the rural housing schemes in Odisha follow a uniform installment pattern. The unit cost for each house is Rs. 1,30,000 in Integrated Action Plan districts and Rs. 1,20,000 in non-integration Action Plan districts. In addition to the financial assistance, beneficiaries are entitled to 90-95 person-days of labor component under MGNREGS. They also receive Rs. 12,000 for constructing toilets under the Swachh Bharat Mission. The funds are released in four installments directly to the beneficiary's account, as follows:

First Installment: After digging the foundation (Rs. 20,000 in IAP districts, Rs. 20,000 in non-IAP districts)

Second Installment: On completion of the plinth level (Rs. 35,000 in IAP districts, Rs. 30,000 in non-IAP districts)

Third Installment: After reaching the roof level and completing the necessary centering and shuttering (Rs. 45,000 in IAP districts, Rs. 40,000 in non-IAP districts)

Fourth Installment: After the completion of the house, including the sanitary latrine affixing the logo, and the beneficiary starts living in the house (Rs. 30,000 in IAP districts, Rs. 30,000 in non-IAP districts)

It can be inspected that the government schemes implemented by the Panchayati Raj & Drinking Water Department in Odisha demonstrate the commitment to providing pucca houses to the houseless and those residing in kutcha houses in rural areas. These initiatives, such as Pradhan Mantri Awaas Yojana (Grameen), Biju Pucca Ghar Yojana, Pucca Ghar Yojana (Mining), and Nirman Shramik Pucca Ghar Yojana, aim to improve the living conditions of vulnerable households, promote inclusive growth, and ensure access to safe and permanent housing. Through these schemes, the Government of Odisha is making significant strides in transforming lives and empowering communities across the state.

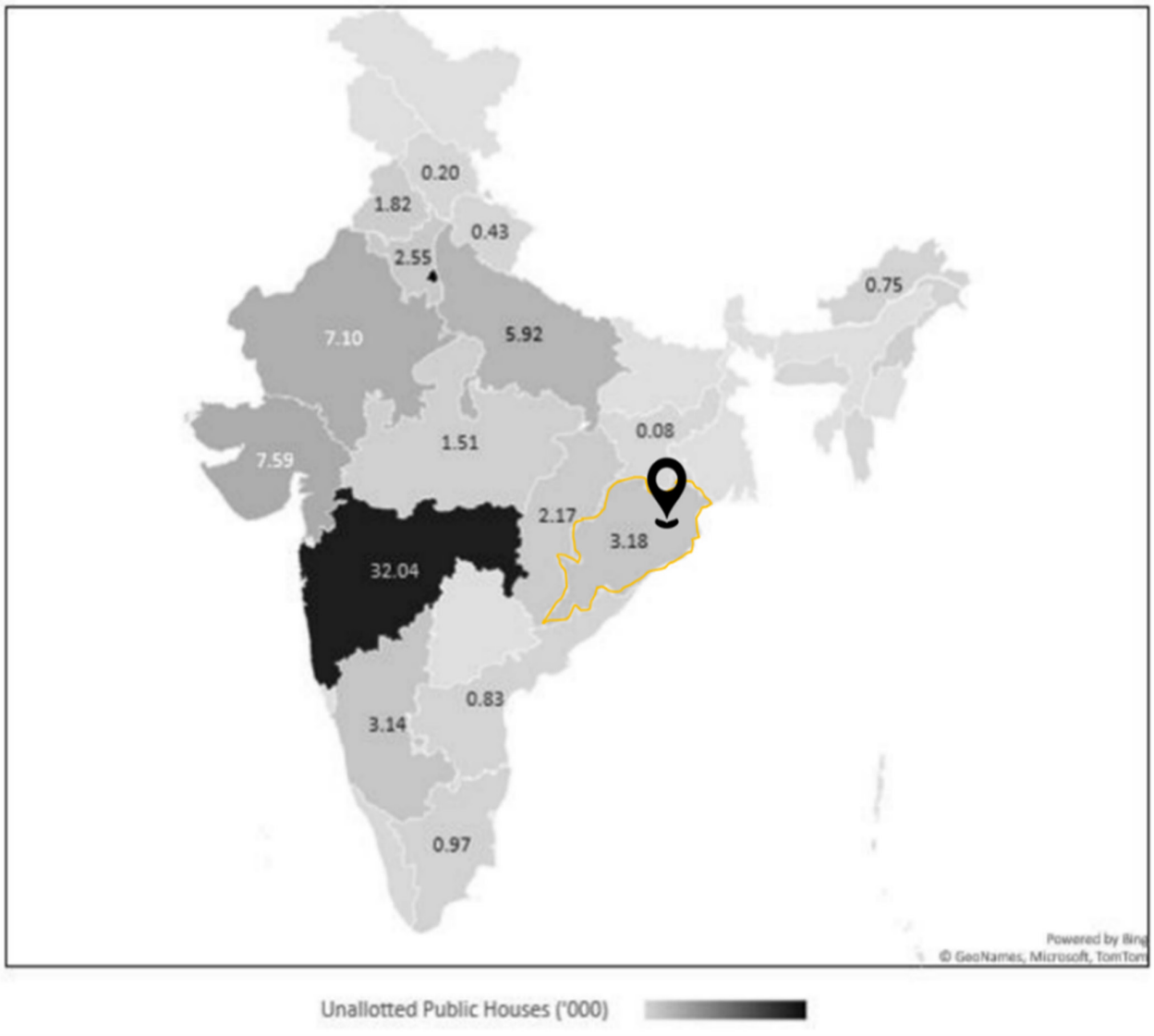
5.2.2 State of Unallotted Public Housing in Selective States of India, 2020

The image below represents the number of unallotted public housing in the states of India sourced from the Ministry of Housing and Urban Affairs 2020 report. According to the image provided, it can be observed that Odisha has a significant number of unallotted/unoccupied public housing units, approximately 3,200. This number accounts for approximately 45% of the total public housing in the state. Each housing unit consists of around 200 units. This implies that the unallotted housing has the potential to accommodate nearly 600,000 families. In the Ministry of Housing and Urban Affairs 2020 report, the central government committed to allocating these unallotted houses to various vulnerable groups, including migrant workers, marginalised individuals, and the economically disadvantaged. This initiative is part of the Affordable Rental Housing Complexes Scheme, implemented under the Pradhan Mantri Awas Yojana (PMAY) program.

Most of the current under-construction affordable housing projects have been planned to be developed at the city's periphery, moving the citizens farther from their source of livelihood. Current discussions often need to pay more attention to the significant issue of vacant housing resulting from the delayed allocation process, despite a general agreement on the reluctance of eligible recipients to relocate to these more remote areas and peripheral locations.

Figure 36: State of unallotted public housing in India (Odisha highlighted)

Source: MoHUA, 2020



Construction worker finishing the top layer of a precast slab

6. Building and Construction Sector in Odisha

6.1 Building Technologies and Construction Practices

Traditional and Local Construction Systems, Rural and Urban Construction Systems

Odisha has been traditionally a region of low-rise construction. It has a wide range of materials in use for various types of construction techniques existing in the state, ranging from the vernacular to the modern techniques depending upon the geography. Bhubaneswar, the capital city of Odisha, has its own set of socio-cultural practices in housing. As a rapidly growing urban centre, Bhubaneswar has witnessed a blend of traditional and modern housing practices and has strong traditional and architectural values of its own. Its vernacular forms of buildings have existed in the region in their primitive forms and have impacted the living conditions and the social values of various districts. Bhubaneswar is renowned for its ancient temples, especially the magnificent Lingaraj Temple and the temples in the Old Town area. The architectural styles of these temples have influenced residential buildings in the city.

Figure 37: Socio cultural practices in housing sector from (a) vernacular to (b) modern

Many houses in Bhubaneswar incorporate elements of temple architecture, such as intricately carved doorways, stone or wooden pillars, and religious motifs.[5] The socio-cultural practices in housing in Bhubaneswar reflect the city's unique blend of tradition and modernity. The city's rich cultural heritage, planned development, and growing urbanisation have shaped the housing practices in Bhubaneswar[6].

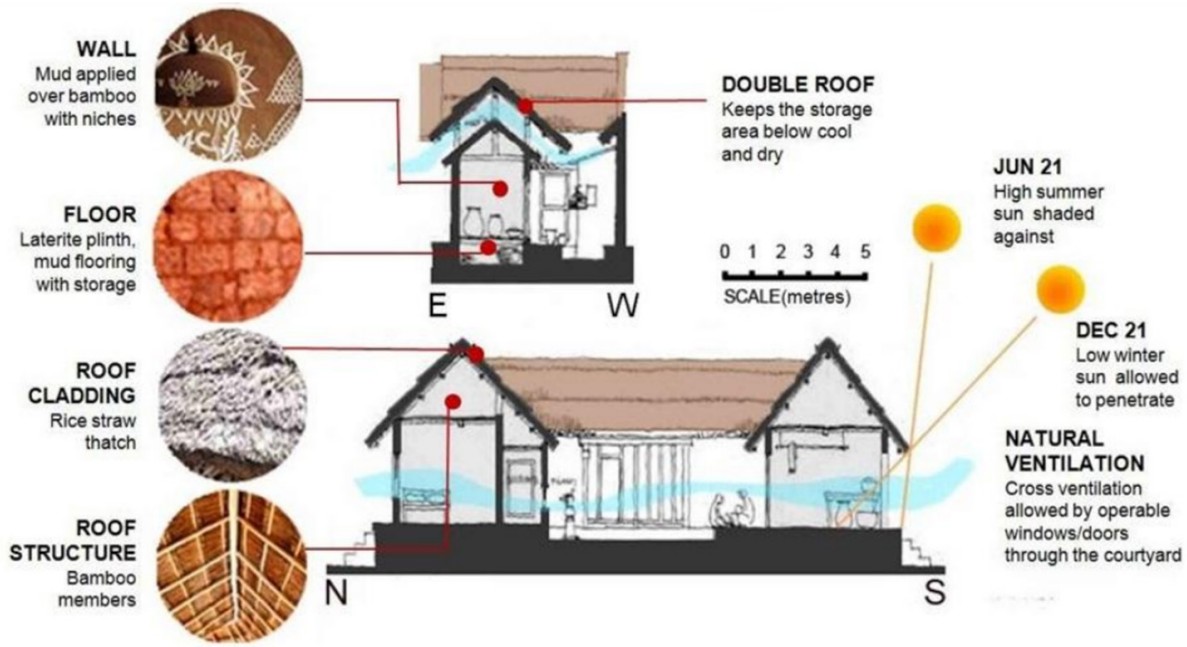
Figure 38: Vernacular Building Materials and Housing practices

5 https://optimizeias.com/odisha-temple-architecture/#:~:text=The%20main%20architectural%20features%20of,ancient%20Tribhuvanesvara%2C%20Puri%20and%20Konark.

6 https://www.researchgate.net/publication/341100086_An_Overview_Of_Vernacular_Architecture_In_India/link/5ead52cf299bf18b958e46d2/download

Figure 39: Building materials and construction technologies commonly used in Odisha housing

Source: Coastal case study, 2018



The building is designed with a sloping roof surface to bear rainfall, a circular house form to combat cyclonic winds, a mud roof that keeps out the sun's heat, and an internal courtyard that makes the shaded open space. The typical Odia house in a village has a stone wall and gable roof on a wood or bamboo frame thatched with straw. The simple village houses have sophisticated design systems like sloped thatch roofs with Attu (mud ceiling with bamboo/timber rafters), Kadi Baraga roofs, etc. The Kadi (timber beam) and Baraga (timber rafter) are applied for flat roofs. Due to the porosity of the Attu built on bamboo or wooden frames, hot air goes out, keeping the building cool in summer and acting as fire protection. Mud has been extensively used because of its easy availability, sound insulation, and good binding properties. This Attu, whose peculiar form is characteristic of this area, is a distinct identity. In Kadi (Baraga roof), the structural arrangement includes Kadi and Baraga without any reinforcement for flat roof construction. Many traditional houses in Odisha, particularly in rural areas, feature a central courtyard called "Aangan[7]." The courtyard is a multipurpose space for social gatherings, festivals, and household chores. The surrounding rooms are built around the courtyard, creating a sense of openness and communal living[8].

6.2 Conventional Practices

The construction practices and technologies in Bhubaneswar, Odisha, have evolved over the years, ranging from traditional practices to upgraded contemporary materials. The major influence to adapt shift in construction technologies from ancient to modern materials is based on the region's unique climatic conditions, cultural influences, temple architecture, and the locally available resources. The traditional construction techniques were based on the rich cultural influences that have been in use for centuries. These techniques often involve low-rise buildings using locally available materials based on climatic conditions, such as using materials that are effective to the occupants in such climatic zones. The buildings were made of locally available materials like stone, mud, timber, and bamboo. Traditional houses in rural areas often feature mud walls with thatched or tiled roofs. The old house has a sloping roof that quickly sheds heavy rain and protects walls from getting damp and absorbing heat from the sun.

The current practices followed in Bhubaneswar for the construction based on the various structural elements are- The total width of openings in a load bearing or shearing wall should not exceed 50% of the length of the wall, no opening

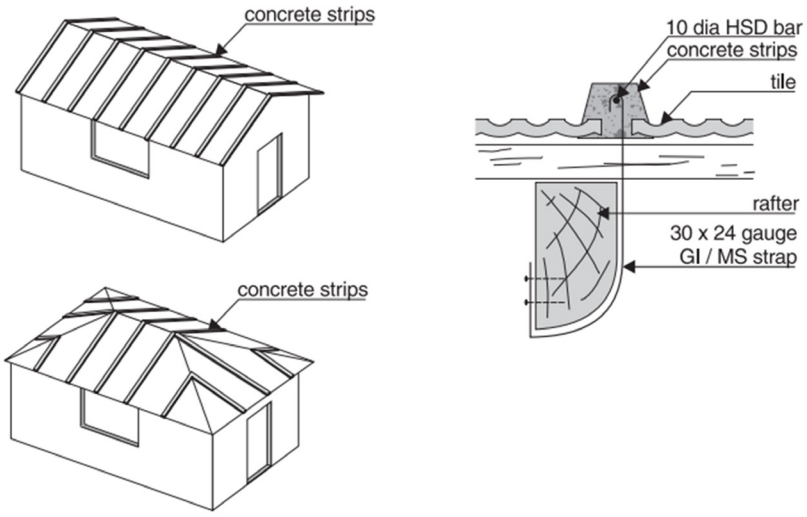
7 https://cdkn.org/sites/default/files/files/Coastal-Case-Studies.pdf

8 https://cdkn.org/sites/default/files/files/Coastal-Case-Studies.pdf

should be located within two times the wall thickness or one-twelfth of the storey height whichever is less, from the cross wall. Reinforced concrete, steel, or timber framing can be used as an alternative to vertical load-bearing walls. The frame comprises rigidly connected beams and columns or posts in R.C.C constructions. In steel and timber constructions, complete structural framing should be adequately braced in vertical and horizontal planes. In the case of a thatched roof, it should be properly tied to wooden framing underneath using organic or nylon ropes in a diagonal pattern. The foundation wall and roof bonding should be tight, and bracings or more concrete bands should be provided in the structure. Adopting improper construction practices in such disaster-prone areas may lead to failures in many cantilever structures, damage to mproperly attached windows or window frames, roof projections, chajjas, and sunshades[9].

Figure 40: Roofing joints in Odisha

Source: Cyclone resilient building architecture, 2007



6.3 Material Usage and Impact on Cooling and Heating

Due to their inherent properties, different building materials respond differently to climatic conditions. The thermal properties of building components such as walls, ceilings, and floors determine an enclosed space's energy consumption patterns and comfort conditions. Different construction techniques and parameters also play a crucial role in maintaining a good building envelope of the space. An elongated floor plan and minimum internal partitions created an easy passage for cross ventilation by reducing friction.

The rate of coolness that can be stored and retrieved in the building structure depends on the **density, specific heat and thermal conductivity of the material, convective** heat transfer coefficient, and the ratio of the heat transfer area to the volume of the thermal storage element. The amount of coolness or thermal energy that can be stored and retrieved in the building mass of many conventional building designs on a daily cycle is limited. In contrast, experience in the old traditional buildings in the hot regions indicates that walls made of local lateritic materials play the role of regular storage of coolness[10]. Thermal insulation was achieved by the effective use of materials and the techniques used to construct walls and roofs. The walls in the east and west are made of brick with natural stone cladding. Natural stone increases the walls' insulative capacity, preventing heat loss from the building through the wall surface. The interior of the walls is smooth and is made of special plaster. The plaster involves the application of the finely ground mixture of powdered shell, lime, jaggery, and spices, including gallnut, to walls[10]. This technique keeps the house's interior cool during the hot and humid Indian summers and lasts a lifetime. The alternative for the walls in such climatic conditions is the construction of walls using hollow bricks, perforated bricks, and concrete blocks. The hollow bricks have air-filled cavities within blocks, which act as insulating pockets, minimising heat transfer and helping to maintain a comfortable indoor temperature. The cavity in the rat

9 https://cdkn.org/sites/default/files/files/Coastal-Case-Studies.pdf

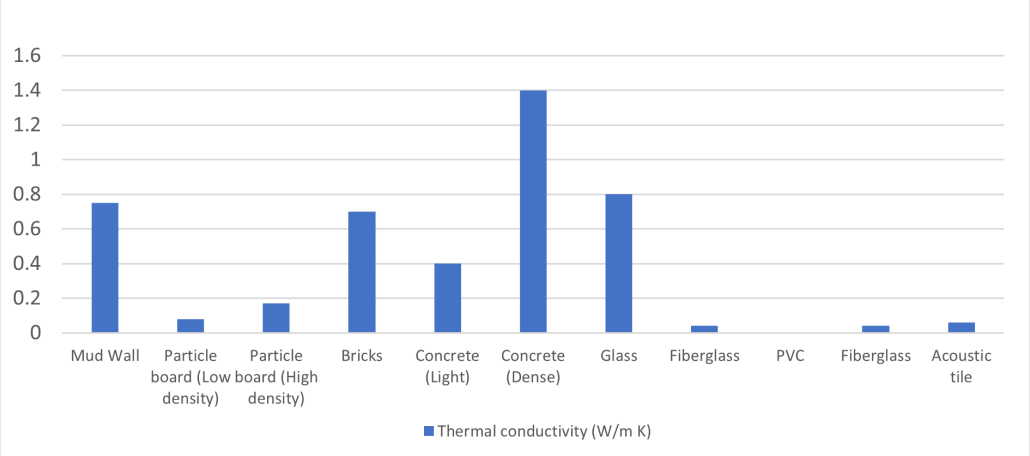
10 Adesanyaetal._Localbuildingmaterialsasarecipeforaffordablehousing.pdf

trap bond acts as an effective insulation barrier, reducing heat transfer through the walls. It helps maintain a cooler indoor environment, particularly advantageous in hot climates like India. The air gap within the walls of a rat trap bond allows for better ventilation and moisture control. It helps to prevent the accumulation of moisture and condensation, which can be a common issue in humid regions. Heat losses and heat gains through masonry walls can be minimised using cavity wall construction. Separating the exterior and interior walls by the cavity eliminates or reduces thermal bridging and allows a large amount of heat to be absorbed and dissipated in the outer wall and cavity before reaching the inner wall and the building interior. The external wall is of exposed brick work.

Table 28: Density-specific heat and thermal conductivity of different building materials

Building materials	Density (kg/m3)	Specific heat (J/(kg K)	Thermal conductivity [11](W/m K)
Mud Wall		880	0.75
Particle board (Low density)	590	1300	0.08
Particle board (High density)	1000	1300	0.17
Bricks	1600	840	0.7
Concrete (Light)	1200	1000	0.4
Concrete (Dense)	2100	840	1.4
Glass	2600	820	0.8
Fiberglass	150	700	0.04
PVC	1400	1250	0.12-0.25
Fiberglass	150	700	0.04
Acoustic tile	290	1340	0.06

Figure 41: Thermal conductivity of different materials



11 https://www.electronics-cooling.com/2008/02/thermal-properties-of-building-materials/

Thermal insulation was achieved by the effective use of materials and the techniques used to construct walls and roofs. The walls in the east and west are made of brick with natural stone cladding. Natural stone increases the walls' insulative capacity, preventing heat loss from the building through the wall surface. The interior of the walls is smooth and is made of special plaster. The plaster involves the application of the finely ground mixture of powdered shell, lime, jaggery, and spices, including gallnut, to walls.[12] This technique keeps the house's interior cool during the hot and humid Indian summers and lasts a lifetime. The alternative for the walls in such climatic conditions is the construction of walls using hollow bricks, perforated bricks, and concrete blocks. The hollow bricks have air-filled cavities within blocks, which act as insulating pockets, minimising heat transfer and helping to maintain a comfortable indoor temperature. The cavity in the rat trap bond acts as an effective insulation barrier, reducing heat transfer through the walls. It helps maintain a cooler indoor environment, particularly advantageous in hot climates like India.[13] The air gap within the walls of a rat trap bond allows for better ventilation and moisture control. It helps to prevent the accumulation of moisture and condensation, which can be a common issue in humid regions. Heat losses and heat gains through masonry walls can be minimised using cavity wall construction. Separating the exterior and interior walls by the cavity eliminates or reduces thermal bridging and allows a large amount of heat to be absorbed and dissipated in the outer wall and cavity before reaching the inner wall and the building interior. The external wall is of exposed brick work.

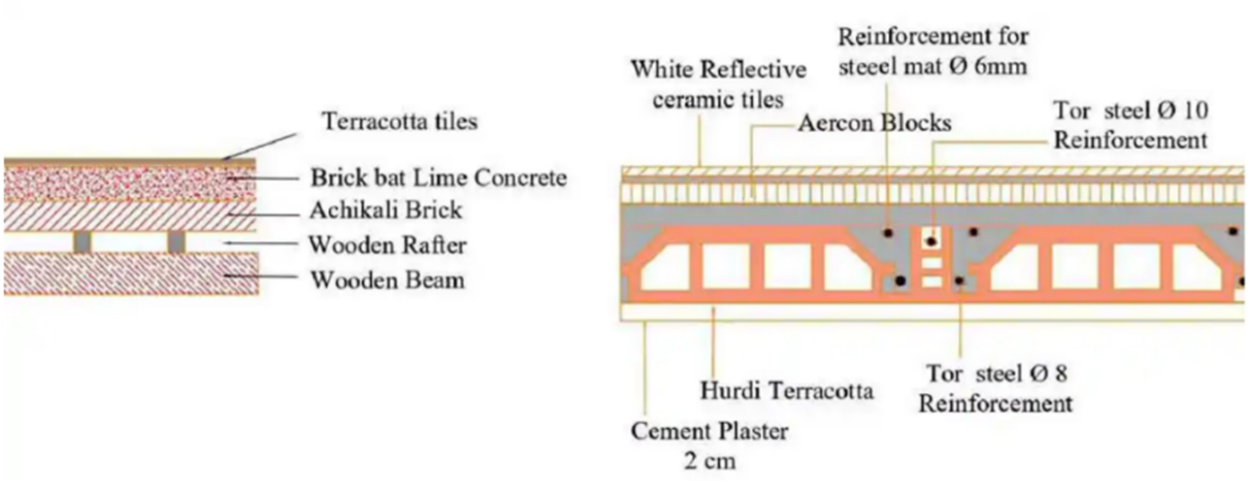
Figure 42: Different types of bricks (a) hollow and (b) rat trap bond for maintaining insulation in building

The roofs can be made using the filler slab, a mechanism to replace the concrete in the tension zone. The filler material, thus, is not a structural part of the slab. By reducing the quantity and weight of material, the roof becomes less expensive yet retains the strength of the conventional slab. Light weight, inert, and inexpensive materials such as low-grade Mangalore tiles, burnt Clay Bricks, hollow Concrete blocks, stabilised mud blocks/hollow mud blocks, clay pots, coconut shells, etc., can be used as filler materials. These materials are laid in the grids of steel reinforcement rods, and concreting/concrete topping is done over them. The air pocket formed by the contours of the tiles makes an excellent thermal insulation layer. Since the heat gain from the roof is the highest, if the filler slab could be done using hollow materials, we get multiple advantages – passive solar cooling where the voids reduce the heat transfer, lesser roof weight due to the hollowness, different looks when seen from the room below, reduced sound transmission between the floors.

12 https://www.researchgate.net/publication/288363877_A_comparative_study_of_the_thermal_comfort_of_different_building_materials_in_madurai/link/5a544588a6fdccf3e2e29f56/download

13 https://www.researchgate.net/publication/326915020_Comparison_of_performance_of_rat_trap_brick_bond_with_the_conventional_brick_bond

Figure 43: Thermally insulated roof



Group housing site at Bhubaneshwar

A stack of paver blocks

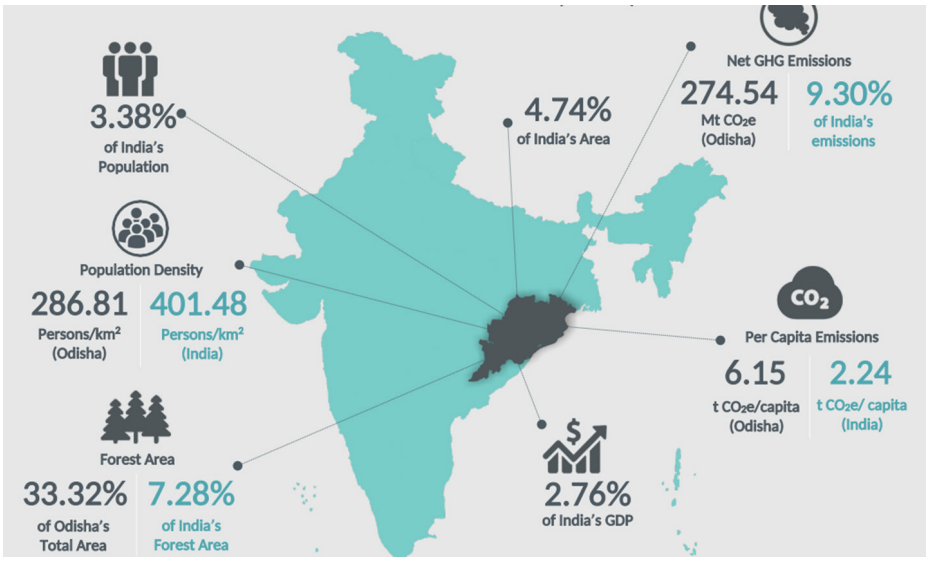
7. Embodied Carbon

7.1 Building Embodied Carbon

7.1.1 Embodied Carbon by Country and Sector

India's building and construction sector holds significant importance, contributing 9% to the country's GDP and employing more than 50 million people. However, it also contributes significantly to India's carbon footprint. According to the IEA's Stated Policies Scenario in India Energy Outlook 2021, CO_2 emissions from existing and new buildings are projected to increase from 194 $MtCO_2$ in 2020 to 245 $MtCO_2$ in 2040.[14]

Figure 44: Per capita GHG emissions of Odisha ad India (2005- 2018)



By 2050, India's total building floor area is projected to reach around 57.6 billion m2, compared to 15.8 billion m^2 in 2015. This growth will drive the demand for conventional construction materials like cement, steel, bricks, and glass, which have significant energy and emissions intensities.[15]

Odisha has witnessed a significant rise in per capita emissions, with an annual compounded growth rate of 6.63% between 2005 and 2018. This increase, reaching 6.15 t CO_2e/capita, is nearly twice that of India's overall growth rate (~3.41%). A major factor driving this surge is the building sector. India's total constructed area is projected to more than double, contributing to a substantial increase in resource consumption. Approximately 40-50% of global resource extraction is directed towards housing, construction, and infrastructure. Notably, 20-25% of India's total energy demand stems from the manufacturing industries responsible for building materials(Laboratories Pvt Ltd Bhubaneswar, n.d.).

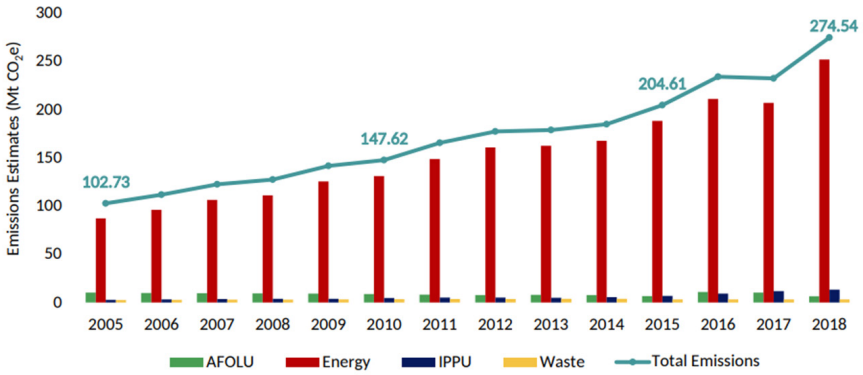
India is the world's second-largest producer of bricks, steel, and cement. The prevalent construction techniques heavily rely on reinforced concrete and steel frames. Notably, 2020 alone saw the consumption of about 60 million tons of cement and 14 million tons of steel for urban construction in India. India's urbanisation rate is projected to reach 40% by 2030-31. This transition towards urban living is driving a rapid escalation in the consumption of energy-intensive construction materials.[16]

14 https://wri-india.org/events/value-chain-approach-decarbonizing-building-and-construction-sector-india-stakeholder
15 https://aeee.in/tackling-embodied-carbon-from-indias-building-sector/
16 https://www.ghgplatform-india.org/wp-content/uploads/2022/09/GHGPI_Trend-Analysis_2005-to-2018_Odisha_Sep22.pdf

In the next 30 years, India's steel demand is estimated to more than quadruple, from around 111 Mt to 489 Mt, and the corresponding CO_2 emissions are projected to rise from around 300 MT to 837MT. In the next 20 years, India's brick demand is projected to multiply by three to four times and reach 750 billion to 1 trillion bricks/year. Brick kilns are responsible for about 66 million tons of CO_2 emissions nationwide. India produced around 337 MT of cement in 2019, corresponding to ~250 Mt of CO_2 By 2050, which could increase by three to six times. At the same time, the Indian cement industry aims to achieve a 45 percent reduction in emissions intensity by 2050 from its 2010 levels.[17]

7.1.2 Greenhouse Gas Emissions

Figure 45: GHG Emissions estimates of Odisha based on different sectors (2005-18)

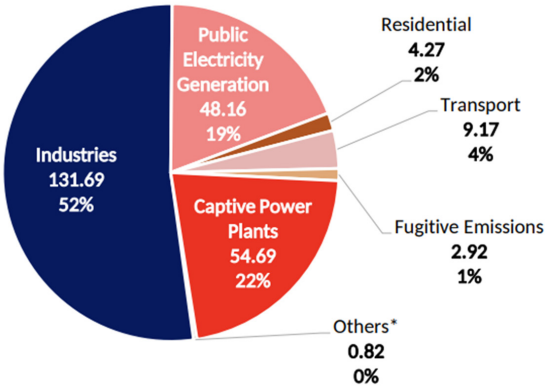


In 2018, the energy sector in Odisha was responsible for approximately 92% of the total greenhouse gas emissions across various categories, including public electricity generation, transport, captive power plants, industries, agriculture, commercial, and residential sectors. The figure above shows the emissions estimates from the various sectors in Odisha and their constant increase ranging from 2005-18. The residential sector alone contributed around 2% of the total emissions, with its recorded emissions reaching 4.27 Mt CO_2e. Fugitive emissions resulting from fuel production were also accounted for in the overall emissions estimation.[18] Emissions of Odisha grew at an estimated CAGR of 7.85%, from 102.73 Mt CO_2e in 2005 to 274.54 Mt CO_2e in 2018. A significant rise in the total emissions was observed in recent years owing to increased Energy sector emissions (Analysis of Greenhouse Gas Emissions from 2005 to 2018, n.d.).

7.1.3 Buildings Embodied Carbon

The carbon footprint accounts for the emissions from production of materials and transportation of materials from production source to construction site. Emissions at the construction stage have not been considered in carbon footprint. These include electricity emissions from on-site operations like welding, concrete vibration, and material trolley. Studies indicate that, given the technology level, construction phase energy varies from 2-4% of the total energy in India. (*Analysis of Greenhouse Gas Emissions from 2005 to 2018*, n.d.)

Figure 46: Emissions from various sectors



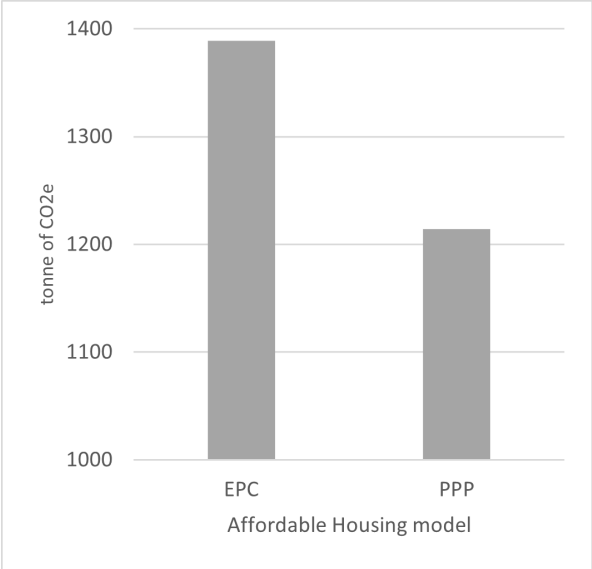
17 https://rmi-india.org/reducing-embodied-carbon-is-key-to-meeting-indias-climate-targets/

18 https://www.ghgplatform-india.org/wp-content/uploads/2022/09/GHGPI_Trend-Analysis_2005-to-2018_Odisha_Sep22.pdf

Tying reinforcement bars for slab casting

Figure 43, provide a breakdown of emissions per tower having the built-up area of 1291.68-meter sq. in a G+4 residential building for the EWS category, considering the quantity and material type used in the construction of the towers. Material flow has been estimated in Mass of building material which is consumed by four main items of construction – Concrete and RCC in foundation and super-structure, Masonry in foundation and superstructure, Flooring, Plastering and Door-window. Considering the type of building technologies, **the carbon footprint is estimated to be 0.94 tonne of CO_2 equivalent per meter sq.** The total built up area of the affordable housing building for G+4 structure is 1477.79-meter sq. for precast technology (EPC Model) and 1291.68 for the framed structure (PPP Model). Based on this the emissions for G+4 Building based on EPC model will be around 1389.11 tonne of CO2e and for the PPP model the emissions will be 1214.17 tonne of CO2e (George & Jacob, 2018).

Figure 47: Emissions per tower having built-up area of 1291.68 m.sq. with G+4 structure (tonne of CO_2e)



7.2 Renovation, Decommissioning, and Recycling

7.2.1 "Age" of the Building Stock and Trends Regarding Actions and Processes for its Renovation, Retrofitting, Refurbishment, or Reuse

The life span of a building generally depends on geographical location, and it is different in countries. Concrete buildings typically have an average lifespan of 75 to 100 years, while conventionally constructed structures (using materials like masonry and wood) last around 120 years. However, for contemporary buildings employing modern techniques (like reinforced concrete and glass curtain walls), this duration is halved to approximately 60 years. Thus, the longevity of buildings is influenced by diverse elements such as weathering patterns, construction materials, soil quality, and more.[19]

19 https://theconstructor.org/question/what-is-the-life-span-of-a-building/

Table 29: Lifespan of various materials in India

Component	Life span (Years)
Substructure	100
Brick masonry	100
RCC Structure	100
RCC Slab	100
Glass	50
G.I. Pipes	30
Flooring materials	75
PVC	50
Paint	15

Table 30: Age of the traditional and model constructed buildings

Characteristics of earthen	Traditional earthen construction	Modern earthen construction
Life span	5–30 years (reported)	50 + years (estimated)
Construction	Non-engineered, foundation sometimes missing	Engineered, attention to details
Common construction technique	Cob, wattle & daub, adobe	CSEB, rammed earth, pored earth
Construction cost	Low	Medium to expensive
Type of labour	Self-help construction	Expensive and trained labour
Stabilisation	Some degree of physical stabilisation, biological stabilisation	Physical, mechanical, and chemical/ inorganic (cement and lime)
Weather resistance	Poor	Good
Termite resistance	Poor	Good
Compressive strength	Low (<3.5 MPa)	Medium (greater than3.5 MPa)
Maintenance requirement	Frequent	None to occasionally
'Re-use of soil' potential	High	Medium-low
Standardisation	No	Some degree of standardisation

Traditional earthen construction in Bhubaneswar has a lifespan of 5 to 30 years and often lacks engineered methods and foundations. Roofs require replacement every 5–15 years. Common techniques include cob, wattle & daub, and adobe, with low construction costs due to local materials and self-help labour. However, frequent maintenance is needed to preserve their condition. On the positive side, traditional earthen construction allows for soil reuse, promoting sustainability (Kulshreshtha et al., 2020).

Modern earthen construction offers enhanced features, lasting 50+ years. Techniques like Compressed Stabilised Earth Blocks (CSEB), rammed earth, and proper foundations provide improved structural integrity and durability. Stabilisation methods with cement and lime increase stability, weather, and termite resistance. Modern earthen buildings have medium compressive strength (over 3.5 MPa), enhancing their load-bearing capacity and performance in different climates and environments (Anand & Deb, 2017).[20]

20 https://www.researchgate.net/publication/339738302_The_potential_and_current_status_of_earthen_material_for_low-cost_housing_in_rural_India/link/5e61f393a6fdccac3ceeb593/download

Transportation of precast slabs across the construction site

8. Construction Supply Chain

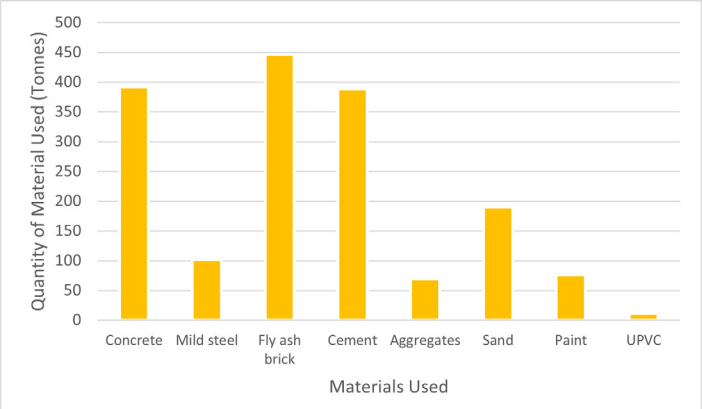
8.1 Material National Production, Importation, and Exportation

8.1.1 Demand Projections of Building Materials

The requirement for building materials and the pace of utilisation are contingent on the construction volume, the increase in per capita built-up area, and the density per square kilometre. The anticipated growth of Odisha's density is nearly twice its present rate. The gross weight of material that flows to every m2 of residential built space is 2-2.5 tonnes.

The material composition for the built-up area of 1291.68-meter square the different types of materials required are as follows: Concrete and Bricks have the highest intensity of utilisation in the construction sector. Bricks account for around 35% of the total material used in the building, followed by RMC, which alone accounts for around 30 % of the total material flow. Sand dominates the quantum of material flow at the primary material, i.e., 15-20%, because of the high volume of concrete and bricks used across the construction sector, combined with cement/fly ash-based masonry units, cement-based mortars and plasters. This is followed by aggregates 5-8% and cement 15-18%. The mineral–based material flow comprising cement, steel accounts for 16-18% of the total flow.

Figure 48: Quantity of different material used in G+4 story structure having built-up area of 1291.68 m.sq.



The growth in material consumption is based on the growth in the population and the increase in the per capita built-up area. The existing pressure on the residential sector will increase the demand for affordable housing. The total demand for the affordable housing sector till 2031 will reach around 2 lakh dwelling units based on the slum population and the city development plan of Bhubaneswar. According to CDP 2031 and the Master plan of Bhubaneswar, the total housing demand will be to eliminate the housing shortage by 2030. The future demand for housing in the BDPA has been calculated at 4.3 lakh dwelling units[21], considering 20% for authorised slum households and 80% of unauthorised slum households as households occupying non-standard dwelling units to compute the qualitative housing shortage.[22]

Based on the total demand of the dwelling units and the projected slum population of Bhubaneswar city, housing demand can be met by constructing the required number of units.

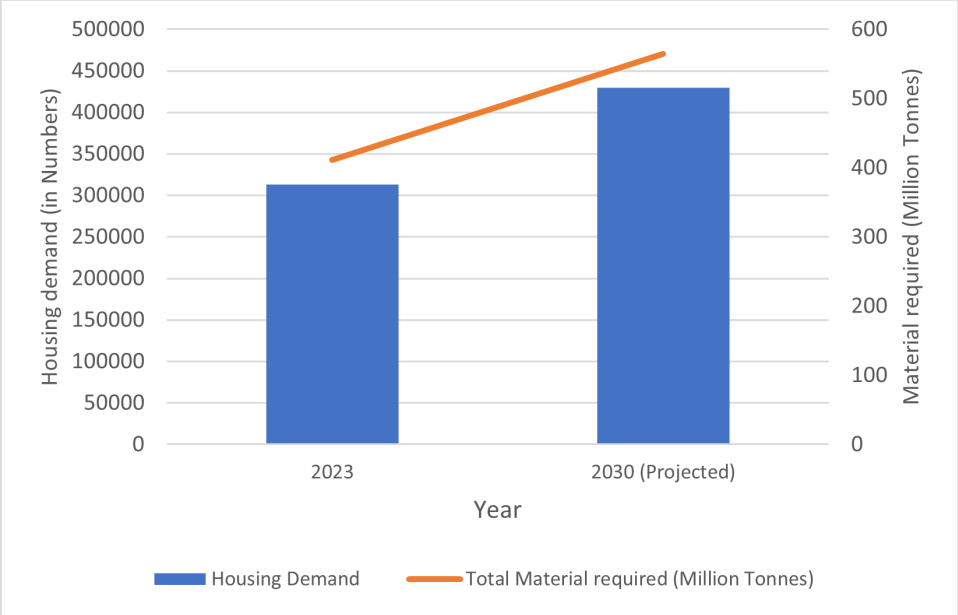
Table 31: Total number of dwelling units for the EWS category in Bhubaneswar

Year	No. of affordable housing Dwelling Units planned[23](Nos.)	Materials required for meeting the demand (Million Tonnes)
2021	3,12,930	10.27
2031	4,31,915	14.11

20 https://iihs.co.in/knowledge-gateway/wp-content/uploads/2017/11/Bhubaneswar-Final.pdf
21 https://www.hindustantimes.com/ht-insight/economy/affordable-housing-in-bhubaneswar-101665654764899.html
22 https://www.hindustantimes.com/ht-insight/economy/affordable-housing-in-bhubaneswar-101665654764899.html
23 CDP- Bhubaneswar, 2031

As per the CDP, the quantitative housing in the Bhubaneswar Development Plan Area (BDPA) for 2030 needs 4.3 lakhs units.[24] The existing 13,70,000 BDPA population will grow to 30,00,000 by 2030. There is an existing backlog of around 15,220 dwelling units. Qualitative shortage and obsolescence raise the total BDPA housing requirement in 2030 to 4,31, 915 units.[25] Based on the 2011 Census, there will be a demand for approximately 1.90 dwelling units to accommodate the increasing slum population, considering the average household size in the city, which is 4.36.[26] To meet the housing demand in Bhubaneswar by 2030, the city requires the construction of 4,31, 915 housing units, out of which approximately one-third, or dwelling units, are to be developed for the EWS category. This growing demand will impact the material consumption to fulfil the requirements of the affordable housing sector of Bhubaneswar. The projected demand for the material requirement till 2030 will reach around 14.11 million tonne. (REPORT ON TREND AND PROGRESS OF HOUSING IN INDIA 2018, n.d.).Figure 49: Projections for housing demand and the material consumption for the projected number of affordable housing units for 2030 (4.3 lakhs).

Figure 49: Projections for housing demand and the material consumption for the projected number of affordable housing units for 2030 (4.3 lakhs)



8.1.2 Resource Footprint of Current Materials

The various materials have been in use for a considerable time and will continue to be utilised until more environmentally friendly alternatives with lower emissions become available. Different building materials, such as cement, steel, concrete, glass, and aggregates, are in varying quantities per cubic meter of construction, impacting the environment during their manufacturing phases. In the case of a G+4 tower structure with 40 dwelling units, a total of approximately 1313.05 tonnes of materials are required, which are further divided into different quantities of these various materials.

As of 2023, the demand for housing units stands at approximately 3,10,000 units. If this demand is met using the current materials, it would result in emissions of around 3.64 million tonnes of CO_2 equivalent. According to PMAY-U, the 2031 projected housing demand for Bhubaneswar in the affordable housing sector is expected to increase to 430,000 dwelling units. To meet this demand, an additional 5.01 million tonnes of CO_2 equivalent emissions would occur.

24 https://nhb.org.in/wp-content/uploads/2019/03/NHB-T&P-2018-Eng.pdf

25 Planning, 'Violations', and Urban Inclusion: A Study of Bhubaneswar, 2017

26 https://knoema.com/atlas/India/Orissa/Average-household-size

Figure 51: Percentage composition of quantity of materials required for a built-up area of 1291.68 m. sq. (G+4 Structure)

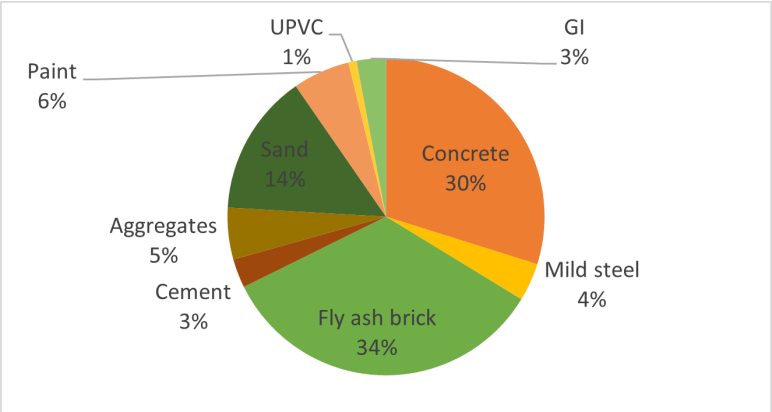


Table 32: Resource footprint of the currently used materials

Materials	Total GWP (Million Tonne CO_2e)	
	2023	2030
Concrete	0.46	0.54
Mild steel	1.45	1.65
Fly ash brick	0.95	1.11
Cement	0.37	0.44
Aggregates	0.006	0.007
Sand	0.018	0.021
UPVC	0.46	0.54
Galvanised Iron	1.3	1.52

The highest carbon emitter is from the steel sector despite having the low usage in the materials. Fly ash brick has large utilisation, however, contributes little in the emissions.

Figure 52: Total embodied energy (MJ) per tower of built-up area 1291.68 m. sq.

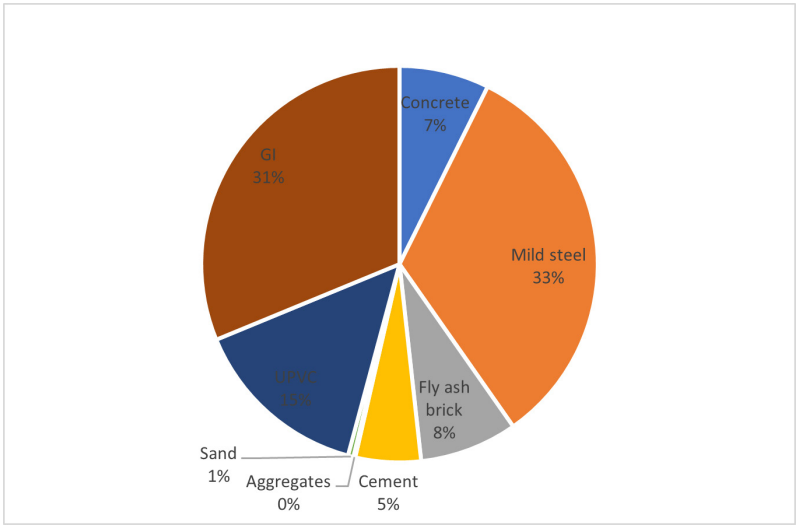
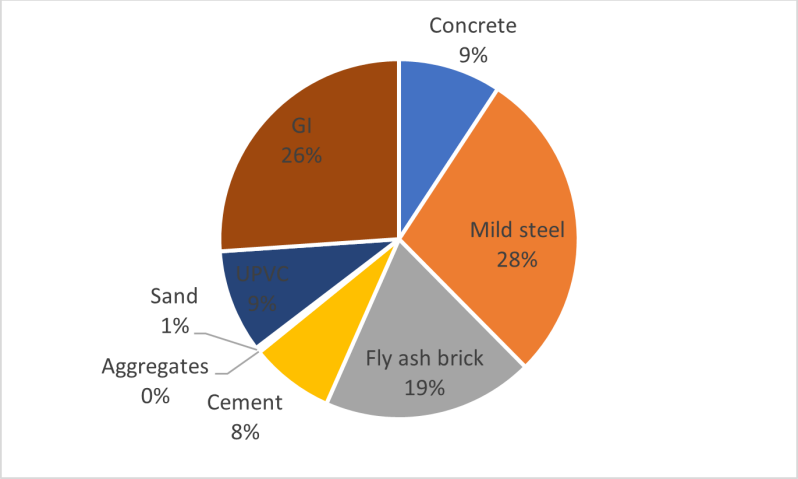


Figure 53:The percentage contribution in the resource footprint. (Based on Bhubaneswar projected data for affordable housing)



8.1.3 Environment Impact

Cement

Cement production releases roughly 0.8 tonnes of CO_2 per tonne of cement to the atmosphere. In the meantime, it is reported that a tonne of Portland cement production produces around a tonne of CO_2 greenhouse gas emissions and about 2% to 8% of global power consumption is due to the cement manufacturing process. Production of cement refers to the method of energy and resource used, which absorbs almost 12% to 15% of total industrial energy utilisation. It also actually reported for 5% to 8% of CO_2 emissions from cement production.[27]

Aggregates

TThe use of crushed stone aggregate and marine sand is increasingly replacing natural aggregate, but these materials also cause various problems, such as ecosystem destruction and transportation-distance challenges. Although the use of recycled aggregate that utilises construction waste is being recognised as a positive phenomenon in terms of the efficient utilisation of resources and the positive environmental aspects, minimising the environmental loads inevitably generated by aggregate production remains an important issue. The environmental impact of recycled aggregate (wet) was up to 16% higher compared with recycled aggregate (dry); the amount of energy used by impact crushers while producing wet recycled aggregate was the main cause for this result. However, in the environmental impact of recycled aggregate, AP, EP, ODP, POCP, and ADP were lower by 37% to 93% than that of artificial light-weight aggregate and slag aggregate.

Steel

The production of primary steel involves various energy sources, coking coal constitutes a substantial 50% of the energy mix, playing a pivotal role in the conversion of iron ore to molten iron in the blast furnace. This is complemented by a significant 35% reliance on electricity, utilised for diverse purposes ranging from powering equipment to facilitating the operation of electric arc furnaces (EAF) during specific stages of steel production. Additionally, 5% each is derived from natural gas and other gases, underscoring their role in providing the high temperatures required at various points in the manufacturing process. The total energy emitted is 1.77 tons of CO_2 emitted per ton of steel produced. The Basic Oxygen Steelmaking (BOS) stands out as the predominant contributor, accounting for 70% of the total production energy. This traditional method employs oxygen to reduce carbon content in molten iron. In contrast, Electric Arc Furnace (EAF) technology, constituting 30% of the total production energy, relies on electricity to melt scrap steel and create new steel.

27 https://www.sciencedirect.com/science/article/abs/pii/S2214785321012943

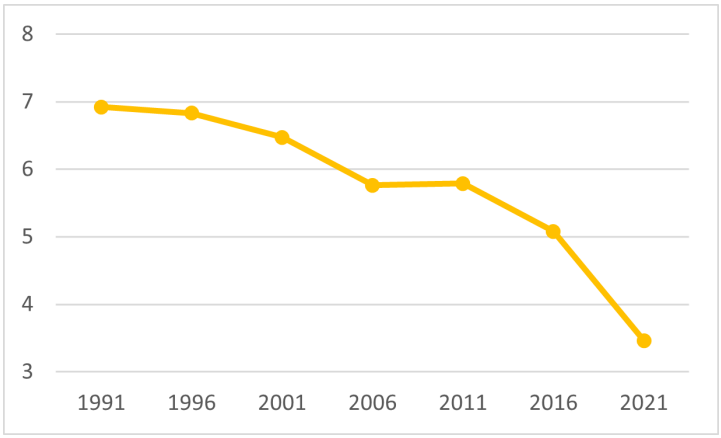
Concrete

The manufacture of one tonne of cement leads to the emission of 780 kg of CO_2. Within this overall CO_2 output, 30% is attributed to energy consumption, while the remaining 70% is a result of the decarbonation process. It is crucial to recognise that despite cement production contributing 5% to the global CO_2 generation, this level of impact underscores the unparalleled and widespread significance of concrete in the construction industry.

8.1.4 Demand Trends (Projection Concerning Pressure on Construction Materials)

The growth trend in the construction material for the Affordable housing sector is based on the growth in the population, slum population, household size, income criteria, and per capita housing requirements. Over the last three decades, the average household size has reduced to half of its 1991 value based on the population increase and the population density of the city of Bhubaneswar[28]. The big gap in the availability of affordable housing for the urban poor is one of the biggest challenges in the region today – more than one-third of the 4.3 Lakh housing units needed by 2030 are in the EWS/LIG category[29]. Multi-storeyed buildings are the preferred technology adopted all over Bhubaneswar for the construction of affordable housing. This will constitute the largest segment in the next 20-25 years as the slum settlements are being rehabilitated.

Figure 54: Decrease in average household size in Odisha



A significant implication of the built form is the quantity of concrete and steel consumed primarily in the RCC frames. While these developments aim to fulfil the housing demand in the city, it is important to address the environmental impact and resource utilisation challenges associated with the construction industry. The construction sector consumes large quantities of raw materials such as cement, steel, and aggregates. The extraction and processing of these materials contribute to environmental degradation and deplete natural resources.

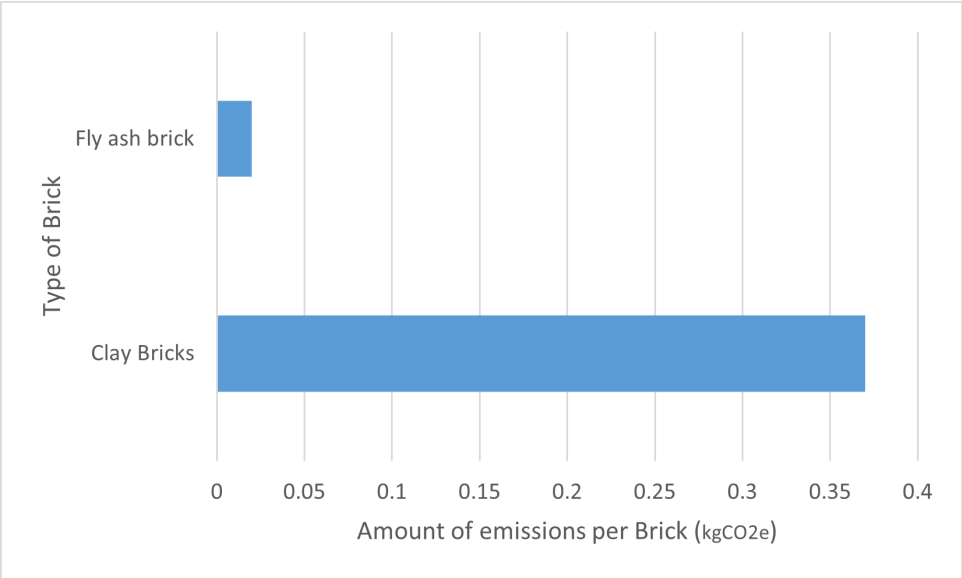
8.1.5 Shift in the Trend of the Material Usage

The construction techniques used in construction in Bhubaneswar are convectional technique. Transitioning from red clay bricks to fly ash bricks in Odisha represents a significant step toward more sustainable and eco-friendly construction practices. Fly ash bricks are produced using fly ash, a waste product generated by coal combustion in thermal power plants. This transition not only promotes environmentally responsible building practices but also makes efficient use of fly ash, a byproduct of coal combustion from thermal power plants. Odisha state has successfully reduced emissions by a significant amount by replacing traditional red bricks with fly ash bricks, resulting in a reduction of emissions to just one-third of the previous levels.

28 https://globaldatalab.org/areadata/table/hhsize/IND/

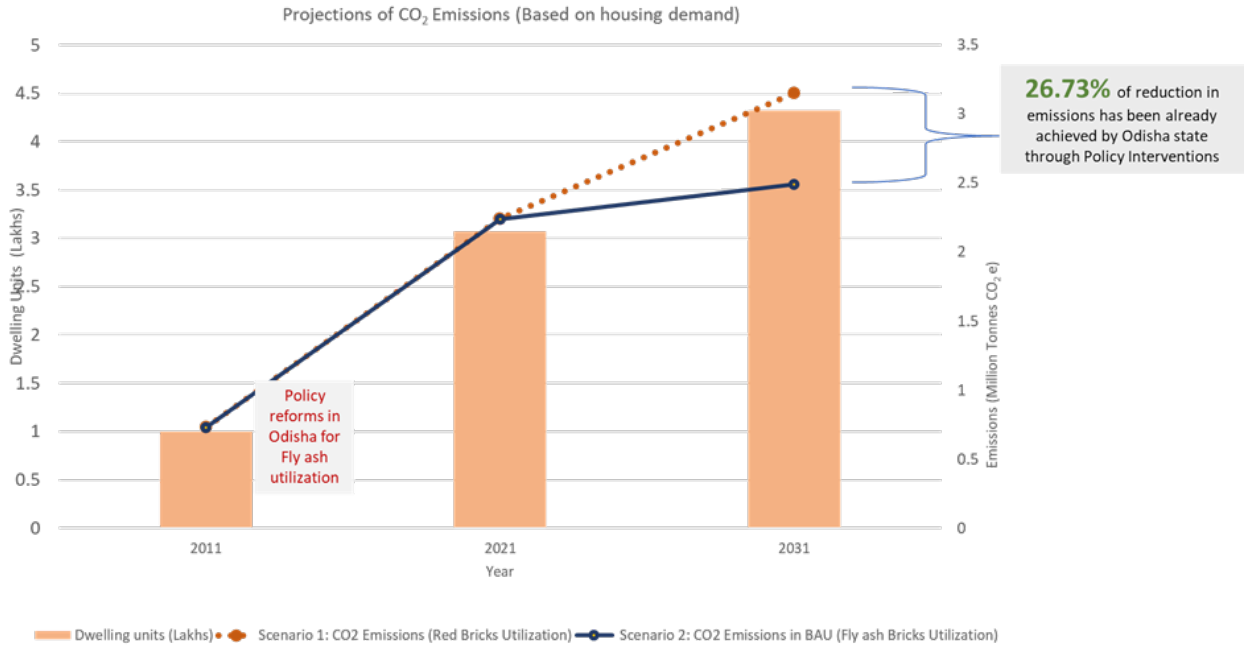
29 Comprehensive Development Plan for Bhubaneswar Development Plan Area (BDPA)

Figure 55: Reduction in emissions per brick



Clay bricks are produced using soil, resulting in significant soil depletion and contributing to soil and land degradation. The soil that could otherwise be used for agriculture is diverted towards brick production, causing extensive degradation of agricultural fields. The consumption of soil for brick manufacturing typically ranges from 3 to 3.5 kg. per brick. The current transition of red brick to fly ash bricks has saved around 26.7% of CO_2 emissions.

Figure 56: Emissions reduction due to shift from red brick to fly ash brick



The Odisha Government has directed the district Collectors to implement the strategy for better construction and demolition (C&D) waste management. Bhubaneswar produces around 200 metric tonnes of C&D waste daily, disposed of in the dumping yard at Patia (Khorda district) and Kargil Road.[30] The city has no initiative to utilise C&D waste, although there is a plan to set up a C&D plant in Bhubaneswar soon. The generated waste primarily comprises waste streams, including majority fractions of soil and masonry. Concrete lumps are also observed.

30 https://csc.urban-industrial.in/hrdpmp/igep-uid/content/e5170/e6258/e14274/e15776/ConstructionandDemolitionWaste_Brochure.pdf

Figure 57: Dumping of C&D waste in Bhubaneswar

Bhubaneswar Municipal Corporation (BMC) has decided to set up a construction and demolition waste processing unit, which will recycle 100 tonnes of such waste a day.[31] PWD, BDA, Odisha Housing Board, commercial large-scale infrastructure businesses, and demolition contractors are among those identified. The waste generated by construction activities varies depending on the type of building activity and typically comprise of broken bricks, tiles, concrete waste, excavated earth, debris, and wood waste. Since there is no practice of using inert material for daily cover, this waste remains uncovered. This generates a considerably foul odor, causing local unrest in neighbouring villages.

8.1.6 Dependency of the Construction Sector on Imported Materials

The construction sector can have varying degrees of dependency on imported materials based on economic development, availability of local resources, and technological capabilities. As per the survey for Bhubaneswar's affordable housing sector, various materials are imported from the neighbouring states. Fly ash bricks commonly used for the construction in the PPP model were manufactured locally within 15-20 km from the sites. The raw materials are transported from various thermal power plants such as NALCO Ltd., Captive Power Plant, Angul, Talcher Thermal Power Station NTPC Ltd., Angul; thus, mainly the raw material for fly ash bricks were supplied from Angul, which is located around 150 Km from the manufacturing unit in Bhubaneswar. Sand is transported from Mahanadi, located near the city, and is transported to different locations based on the manufacturing unit, which ranges from 20-50 Km Radius. Quarts used for the manufacturing of Glass are available in Odisha as the mining is done in the state. Most of the manufactures were using Dalmia cement, mainly transported from Chhattisgarh. PPC and OPC are transported from Vizag, Andhra Pradesh, as no plant is located in the state. Limestone is supplied to the cement plant from a radius of 10- 50 Km. Lime gypsum is transported from Katni Rajasthan and is used as the raw material in the manufacturing plants. Aggregates are supplied from Tapang, which is situated at 50 Km Radius from the Site. The raw material for doors and windows, such as UPVC, is supplied from Faridabad to the manufacturing units within 10-15 km from the affordable housing sites. Then, these frames are cut into proper shapes and supplied to the sites from the plant (Odisha Electricity Regulatory Commission, n.d.).

31 https://timesofindia.indiatimes.com/city/bhubaneswar/bmc-to-set-up-construction-waste-processing-unit-in-city/articleshow/98056117.cms?from=mdr

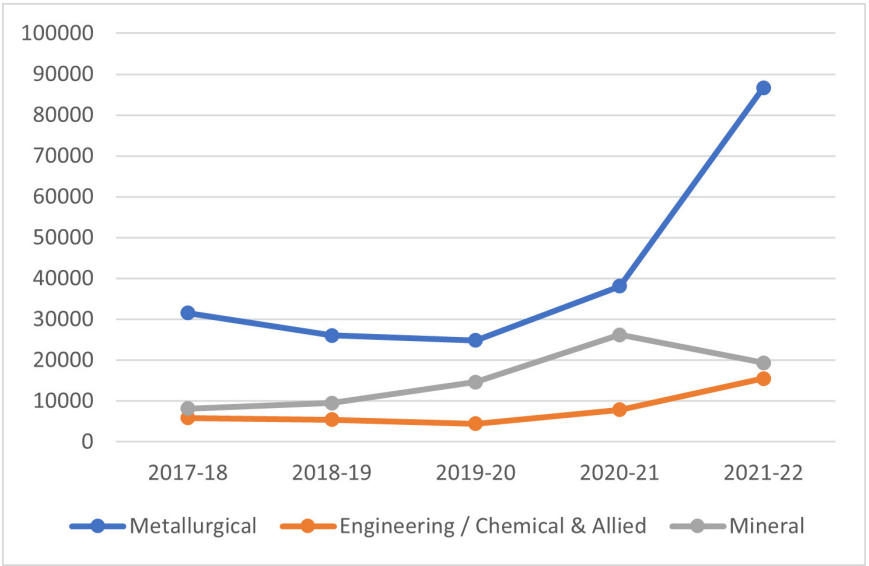
Table 33: Imports from other states for various building materials

Raw Material	Manufacturing plant location- city	Distance from the plant
Cement (OPC)	Vishakhapatnam (Andhra Pradesh) Chhattisgarh	400- 500 Km.
Steel	Jamshedpur (Jharkhand)	400 Km
Fly ash	TALCHER Angul, Jhajpur	200 km
AAC Blocks	Bhubaneswar	20-30 Km
RMC	Bhubaneswar (RDC Concrete)	20-30 Km.
Lime Gypsum	Katni (Rajasthan)	2000 Km
UPVC	Faridabad	1500 Km
Quartz	Odisha state	40- 50 Km
Sand	Mahanadi	20-50 Km
Aggregates	Kavjhar, Duburi	30, 150 Km

8.1.7 Trading: Identification of Construction Materials Imported and Extracted for Exports

The export sector of Odisha is experiencing a consistent upward trend. The export category encompasses a range of products, including minerals like iron ore, chrome ore, and manganese ore, and metallurgical items like charge chrome, ferrochrome, aluminium, alumina, and ferromanganese. The state's contribution to India's overall exports has grown from 2.7% in the fiscal year 2017-18 to reach 4% by the year 2021-22. Analysing the primary export landscape of the state between 2019-20 and 2021-22 reveals that a significant portion of Odisha's exports is centred around mineral and metallurgical commodities. [32] The quantity of exports originating from Odisha's coastline has experienced a notable increase. The total count of exports for metallurgical products, which stood at 40 countries for the fiscal year 2015-16, has now expanded to cover 97 different countries by the fiscal year 2021-22. This represents nearly a twofold rise in the number of countries compared to the count recorded in 2015-16, and for the minerals the export has raised to 42 countries in 2021-22 which was only 5 countries in 2015-16.

Figure 58: Major exports from material and minerals sector (Value in crores)



32 Odisha state economic survey, Govt. of Odisha

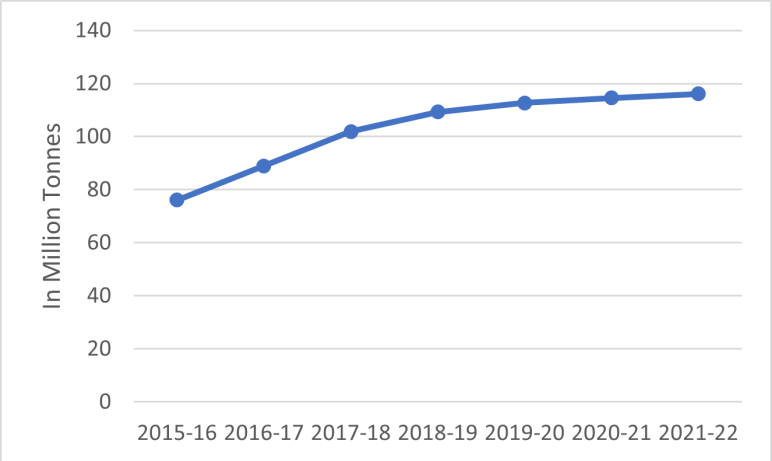
Table 34: Rise in export from Odisha 2015-16 to 2021-22

Category	Number of Countries to which exported during		
	2015-16	2020-21	2021-22
Metallurgical	40	92	97
Engineering & Chemical	79	111	119
Minerals	5	41	42
Agriculture and Forest	4	24	26
Marine	39	33	37
Handloom	13	8	9
Handicraft	7	19	25
Textile	2	17	28
Pharmaceutical	3	27	42
Electronics and software/ Others	6	40	52

Having 480 km of coastline, Odisha has 14 potential sites for minor ports development. These minor ports are located at Gopalpur, Bahuda Muhan, and Palur in Ganjam district; Baliharchandi & Astaranga in Puri district; Jatadhar Muhan in Jagatsinghpur district; Inchri, Chandipur, Bahabalpur, Kirtania and Bichitrapur (Talasari) in Balasore district; Dhamra & Chudamani in Bhadrak district and Riverine port in Kendrapara district. Dhamra and Gopalpur ports are commercially operational. Cargo handled by Dhamra and Gopalpur ports was 33.4 MMT and 8 MMT, respectively, by the end of 2021-22. The government of Odisha is making efforts to develop three other non-major ports, i.e., the port at Subarnarekha mouth (Kirtania), the riverine port on Mahanadi River in Mahakalapada block of Kendrapara district, and Astaranga port of Puri district are in the pipeline in PPP mode[33]. Indian Oil Corporation Ltd (IOCL) is constructing an LPG import facility in Paradip, Jagat Singh pur, Odisha, India. The project involves the construction of a 0.6 MTPA LPG import facility[34]. The LPG import facility involves the construction of various infrastructural elements, including storage tanks, loading/unloading facilities, pipelines, and supporting structures. This contributes to the growth of the construction sector by providing opportunities for civil engineering and infrastructure development.

Figure 59: Cargo handled at Paradip port (in million tonnes) Odisha

Source: Paradip port trust



33 Ministry of Ports, Shipping and Waterways, GOI

34 Directorate Of Export Promotion & Marketing (depmodisha.nic.in)

8.1.8 Responsibly Sourced Materials / Recycle-friendly Materials

Bhubaneswar is increasing environmentally conscious practices by incorporating recyclable materials to be utilised as building materials by adopting technological changes in the construction sector. The state has witnessed a growing emphasis on the utilisation of building materials manufactured from industrial waste, agro waste, mining waste, etc. Odisha state is one of the largest produces of various minerals and contributes enormously to the generation of waste from the various sectors. The state is performing various research to convert these wastes and the by-products into building materials.

Industrial waste, such as fly ash and blast furnace slag, which were previously left unused, is now being transformed into valuable resources for the construction industry. The waste from agricultural products like rice and wheat straw husk and cotton stalks can be used to manufacture briquettes or non-structural parts of the building, saving some of the raw material. The mining waste, such as coal washeries waste, mining waste, tailings from iron, and copper can be used to manufacture Bricks, tiles, Lightweight aggregates, etc. (Chandra Pattanaik, 2010).

The utilisation of waste in building materials promotes sustainable construction practices. It reduces the reliance on raw materials, thereby conserving natural resources. This approach also contributes to a lower carbon footprint by minimising the need for energy-intensive extraction and production processes associated with traditional building materials.(Bhawan et al., 2020).

Table 35: Types of solid waste and their possible utilisation in Odisha

Types of solid waste[35]	Source details	Recycling and utilising in building application
Agro waste	Baggage, rice and wheat straw and husk, cotton stalk, sawmill waste ground nutshell, jute etc.	Particle board, insulation boards, wall panels, roofing sheets fuel, binder fibrous building panels, bricks, polymer composites, cement board.
Industrial waste inorganic	Coal combustion residues, steel slag, bauxite red mud, construction debris	Cement, bricks, blocks, tiles, paints, aggregates, concrete, wood substitute, products, ceramic products
Mining/ Mineral waste	Coal washeries waste, mining waste, tailings from iron, copper, zinc, gold, aluminium industries	Bricks, tiles, Lightweight aggregates, fuels
Non-hazardous other process waste	Waste gypsum lime sludge, limestone waste, marble processing, residues broken glass and ceramics, kiln dust	Gypsum plaster, fibrous gypsum boards, bricks, blocks, cement clinker, super sulphate cement, hydraulic binder
Hazardous waste	Metallurgical waste tannery waste	Cement, bricks, tiles, ceramics and board

8.2 Raw Material Extraction

8.2.1 Identification of Locally Available and Extraction of Raw Materials According to Source and Geographic Location

Odisha is located on the eastern seaboard of India and is richly endowed with diverse mineral resources. These resource availability plays a huge role in the country's development and economic growth. These valuable resources serve the state's needs and are transported beyond its borders to other regions within the country, and a considerable portion is earmarked for export purposes (Odisha Department of Steel and Mines, 2009).

35 https://www.academia.edu/49209417/A_Study_of_Present_Status_of_Waste_Materials_in_the_State_of_Orissa_for_Utilization_in_Making_a_Green_Building

Table 36: Raw material extraction and the quantity extracted

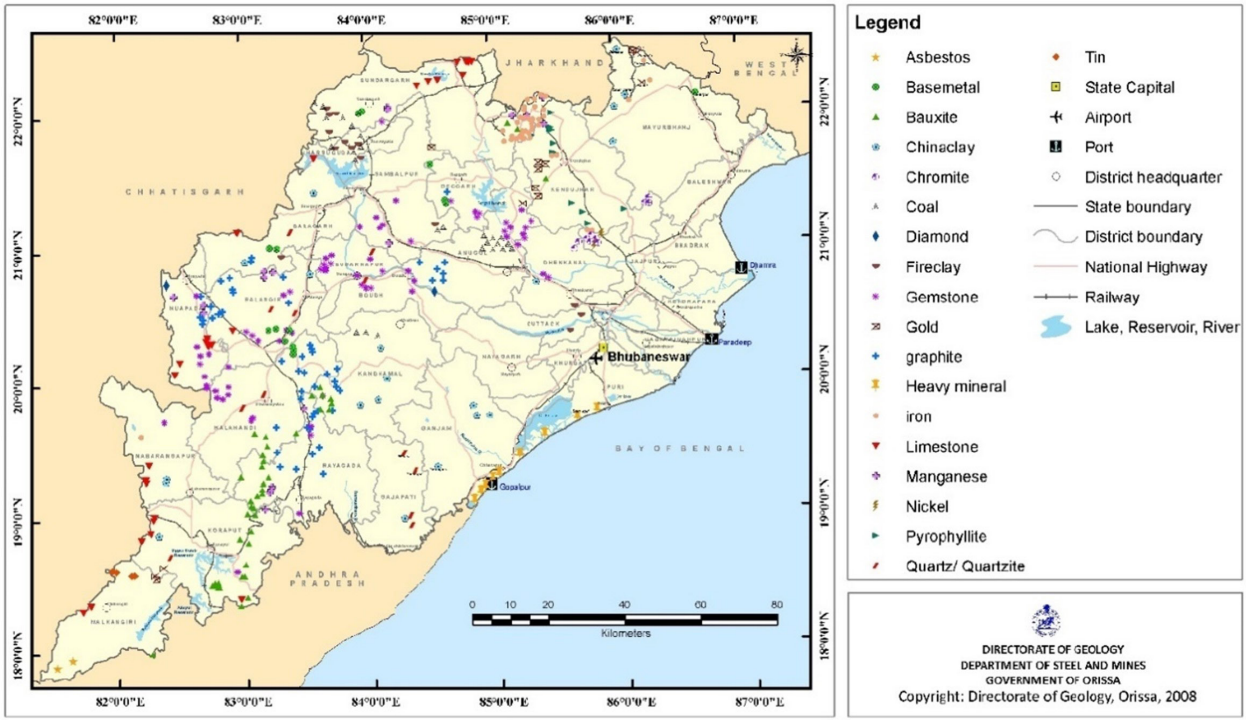
Mineral[36]	Distribution/Districts	Availability	Uses
Bauxite	Koraput, Rayagada, Malkangiri, Kalahandi, Kandhamal, Kendujhar, Sundargada	1810 million tonnes	Aluminium industry Refractory industry Chemical industry Petroleum industry
Iron ore	Kendujhar District, Sundargada, Mayurbhanj, Jajpur	5153 million tonnes	Pig iron, Sponge iron, Steel, Blast Furnace, Alloys
Manganese	Kendujhar, Sundargada, Rayagada, Balangir	119.81 million tonnes	Iron and Steel, Industry, Ferro manganese industry Dry cell (battery), Chemical industry
Sand	Ganjam, Puri coast	226.24 million tonnes	
Asbestos	Malkangiri District		Used in cement products such as asbestos cement sheets, pipes, brake. linings, insulation mill boards, asbestos paper, and fireproof paints, clothes etc.
China clay	Mayurbhanj, Kendujhar, Nawarangpur, Rayagada District, Baragada District	314 mt.	Ceramic, pottery industry, cement industry, textile, paper, rubber, paint
Coal	Anugul, Dhenkanal, Sambalpur, Jharsuguda Dist.	65226.86 Million tonnes	Thermal power plant
Fire Clay	Cuttack District Khurda District Anugul District Baragada District Ib River Coalfield	175.53million tonnes	Refractory bricks
Limestone	Sundargada, Koraput, Malkangiri, Nuapada, Balangir, Baragada	1007.2million tonnes	Cement Industry Iron and Steel Industry Glass industry Chemical industry Sugar industry
Stone	Dhenkanal, Gajapati, Ganjam, Nawarangpur, Nuapada	463.53 million cubic metres	
Quartz	Boudh, Baragada, Kandhamal, Kendujhar, Jharsuguda, Kalahandi, Mayurbhanj, Nuapada, Subarnapur, Nabrangpur, Rayagada & Koraput.	70.30million tonnes	

36 https://www.odishaminerals.gov.in/Download/geology_mineral_resources_orissa.pdf

8.2.2 Minerals (Non-metallic and Metal Ores)

Minerals (non-metallic and metal ores)

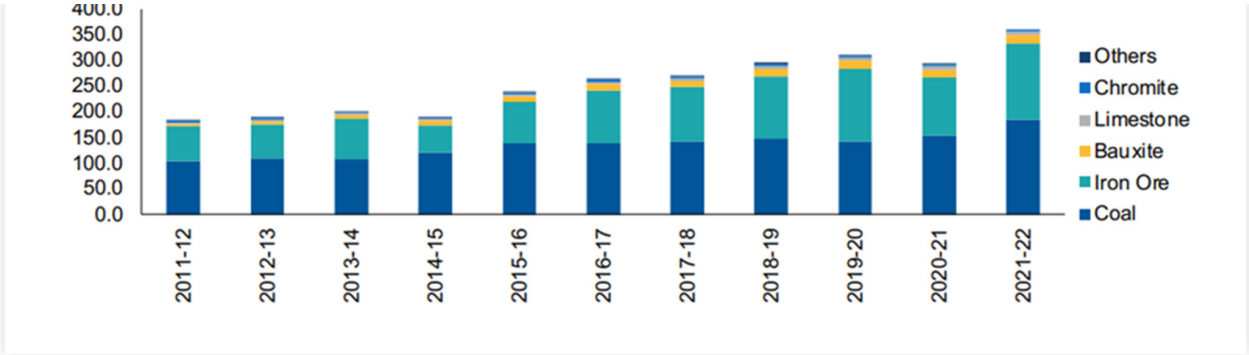
Figure 60: Location map for various raw materials and minerals in the state



Odisha is a mineral-rich state occupying a special position in the mineral map of India. It is endowed with large varieties of metallic and non-metallic minerals, which include chromite, bauxite, graphite, and iron ore. Out of total mineral production, coal and iron ore taken together constitute about 90%. The mineral production in the State is increasing from the year 2011-

12 to 2021-22, except 2014-15 and the covid year (2020-21) when the mineral production slightly declined. However, the average growth rate in mineral production is about 10 % from 1994-95 to 2010-11 and it remained at a level of 6.1 % from 2011-12 to 2021-22[37].

Figure 61: Mineral production in Odisha (Million tonnes)



36 Department of Steel & Mines, Odisha

Minor Minerals

Minor minerals include building stones, gravel, ordinary clay, ordinary sand other than sands used for prescribed purposes, and any other mineral notified in the official Gazette by the Government of India. Accordingly in Odisha, the following minerals have been identified as minor: 1. Quartzite 2. Pyrophyllite 3. China clay 4. Dolomite 5. Soapstone 6. Fire clay 7. Silica sand 8. Sandstone.[38]

Table 37: Production of various major mineral in Odisha (2018- 2022) (Production in lakhs tonne)

Minerals/ Ores	2017-18	2018-19	2019-20	2020-21	2021-22
Iron ore	1049.8	1209.7	1424.6	1126.0	1473.64
Chromite	36.5	40.7	39.2	27.9	37.73
Coal	1433.3	1453.9	1428.0	1539.4	1849.71
Bauxite	113.7	154.2	154.8	156.8	164.49
Limestone	51.1	50.6	56.5	71.7	70.60
Graphite	0.2	0.6	0.7	0.2	1.53
Manganese ore	5.4	4.8	5.4	5.0	5.14

Production of Iron and Steel

There are 51 steel plants in Odisha now, with a total installed capacity of around 33.2 MTPA in operation, constituting almost one-fourth of the country's total installed capacity.[39]

Production of Aluminium

Aluminium is garnering broader acceptance, and its demand is on the rise in India and globally. This surge can be attributed to its lightweight nature, infinite recyclability, high durability, and environmentally friendly advantages, including a reduced carbon footprint and energy requirement during recycling. The southwestern region of Odisha boasts a significant reserve of bauxite, accounting for 65% of the nation's total bauxite deposits, with a substantial 95% concentrated in four districts of the Eastern Ghats: Koraput, Kalahandi, Rayagada, and Bolangir. Notably, the cumulative aluminium production in the state stood at 36.9 lakh MT in 2019. By 2022, this figure had surged to 40.1 lakh MTs, reflecting an impressive growth rate of approximately 12% over the preceding year, further highlighting the region's upward trajectory of aluminium production (Geology and Mineral Resources of Orissa, n.d.).

Table 38: Aluminium production in Odisha (in Lakhs MT)

Name of the Company	2019	2020	2021	2022
NALCO	4.40	4.18	4.18	4.60
BALCO	5.72	5.63	5.68	5.80
HINDALCO	12.94	13.14	12,28	12.94
VEDANTA Pvt Ltd	13.88	13.43	13.72	16.78
Total	36.94	36.38	35.86	40.12

38 Directorate of Mines, Odisha

39 Ministry of Mines, March 2022

Major Minerals

Within Odisha's total mineral production for the fiscal year 2021-22, coal emerges as the dominant contributor, accounting for over 50%. The Angul district holds a good amount of share in coal production, contributing around 52%, followed by Sundargarh (24%), Jharsuguda (21%), and Sambalpur (3%).

Manganese ore production is predominantly attributed to the Jajpur district, accounting for 83% of the output. Meanwhile, iron ore extraction in the same period constitutes approximately 41% of the overall mineral production. The primary districts involved in iron ore mining include Keonjhar (61.93%), Sundargarh (33.81%), Jajpur (2.88%), and Mayurbhanj (1.38%). Bauxite ore, constituting about 4.5% of the state's mineral production, sees distribution primarily between two districts. The Koraput district contributes 60% of this output, while the Rayagada district shares the remaining 40% (Geology and Mineral Resources of Orissa, n.d.).

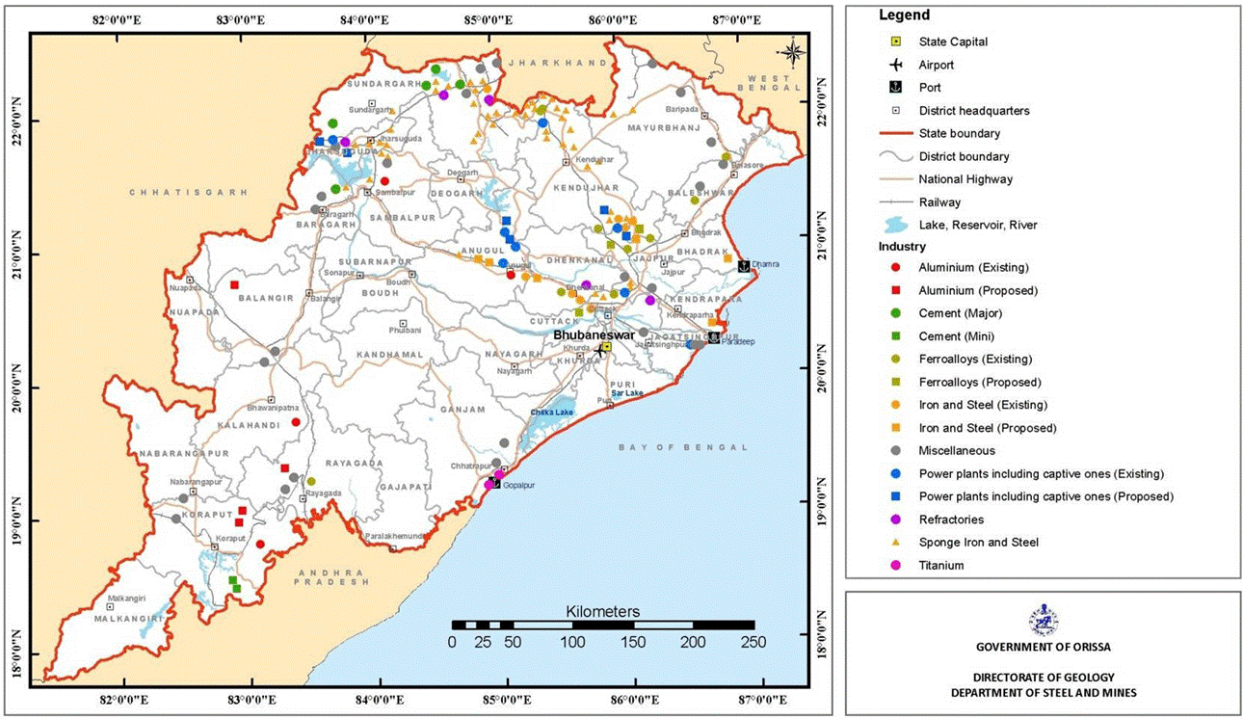
Table 39: District-wise mineral deposits

Source: Department of Steel and Mines, Govt. of Odisha

District	Major minerals
Koraput	Bauxite, China clay, Dolomite, Limestone, Mica, Quartz
Mayurbhanj	Asbestos, Fireclay, China clay, Iron Ore, Kyanite, Quartzite, Soapstone, Talc, Base metal (Lead and Copper), Coal, Dolomite, Manganese, Nickel Ore, Vanadiferous/Magnetite, Gold.
Malkangiri	Limestone, Tin ore, Quartz
Nabarangapur	China clay, Iron ore.
Rayagada	Bauxite, Graphite, Manganese, Quartz
Sundergarh	Lead, copper, Coal, Dolomite, Fireclay, Iron ore, Limestone, Manganese, Quartz, Bauxite,
Sambalpur	Coal, Base metal (Lead and Copper), China clay, Fireclay,
Keonjhar	Asbestos, Pyroxenite, Iron Ore, Chromite, China clay, pyrophyllite, Manganese, Gold, Dolomite, Limestone, quartzite, Quartz
Kadhamal	Graphite
Balasore	Vanadiferous/magnetite
Phulbani	Graphite

Figure 62: Location of various industries in the state

(Source: Department of Steel and Mines)



The state can be divided into twelve industrially active zones/areas based on minerals namely:

- Rajgangpur Area (Iron & Steel, Sponge Iron, Cement, Secondary steel. Melting and rolling mill & refractories and chemicals)
- Ib valley area (Thermal power, Sponge iron, refractories, and coal mines)
- Hirakud area (Aluminum & rolling mills)
- Talcher-Angul area (Thermal power, Aluminum, Coal washeries, Ferro alloys, Coal mines)
- Choudwar area (Ferro alloys, Thermal power, pulp and paper, coke oven)
- Balasore area (pulp and paper, ferro alloys, rubber industries)
- Chandikhol (stone crusher, coke oven)
- Duburi (Integrated steel, ferro alloys, rubber industries)
- Paradeep area (fertiliser, sea food processing, petroleum coke)
- Khurda Tapang area (stone crusher)
- Joda Barbil area (iron, sponge iron, ferro alloys, iron ore crusher, mineral processing)
- Rayagada area (pulp and paper, ferro alloys)[40]

Iron ore is abundantly available in Mayurbhanj, Sundargarh, Keonjhar, and Jajpur districts. While chromite is confined to Jajpur, Dhenkanal, and Keonjhar districts, manganese deposits are available in Sundargarh, Keonjhar, Rayagada, and Balangir districts, and Dolomite is available plentily only in the district of Sundargarh. Two major coal bearing areas in the state are currently being exploited, namely Talcher and the Ib valley[41].

40 https://odishaminerals.gov.in/MiningInOdisha/MineralBasedIndustries

41 https://www.odishaminerals.gov.in/sites/Download/Compendium_of_Mineral_Resources_in_Odisha.pdf

8.2.3 Timber and Bamboo

Figure 63: Timber and bamboo production and utilisation as fuels

Odisha produces abundant bamboo annually; the production is around 2 lakh MT annually, of which about 50,000 MT is produced from private land. Though the cultivated species (Bambusa vulgaris & Bambusa nutans) occur throughout the state, density is significant in the Mayurbhanj, Balasore & Bhadrak districts. Odisha has also formulated the Odisha Forest Developmental Corporation for properly monitoring bamboo production in the state. Out of the total bamboo production, the major part is exported and is not utilised by the state.

Odisha Forest Developmental Corporation has been catering to the sawing needs requirement of Domestic and industrial consumption through its 9 Sawmills situated at Berhampur (Ganjam), Khapuria (Cuttack), Jeypore (Koraput), Maithili (Malkanagiri), Nowrangpur, Remed (Sambalpur), Muniguda, Kantabanjhi and Rourkela[42].

Table 40: Timber and firewood production (Cum.)

Year	Timber Production	Firewood Production
2015-16	59133	31713
2016-17	34233	28904
2017-18	26814	23902
2018-19	34445	29376
2019-20	25001	22041

Housing is a major sector with the consumption of bamboo. Due to its strength and diversity in applications, apart from scaffolding, bamboo is used in flooring, door and window frames, roofing, composite boards, and prefabricated houses. Several opportunities for prefabricated bamboo buildings and bamboo toilets are already been demonstrated by at least a dozen public and non-governmental institutions. Bamboo, having vast features, is underutilised in the construction of the structural part in Odisha's construction sector. The Production quantity of Industrial Bamboo and Commercial Bamboo during the last five years is shown below:

42 https://www.odishafdc.com/bamboo.php

Table 41: Production of industrial bamboo and commercial bamboo

Year	Production of	
	Industrial Bamboo (in SU)	Commercial Bamboo (in nos.)
2014-15	3213.57	52304
2015-16	17748.40	119448
2016-17	4587.00	369590
2017-18	9268.45	449413
2018-19	3748.78	306562
2019-20	3860.48	294663

The state is underutilising its timber, bamboo, and firewood resources, failing to reach their full potential. A significant avenue for their effective consumption and utilisation lies in the production of briquettes. This approach can potentially replace a considerable portion of the fuels currently employed within the state. By doing so, it can play a vital role in curbing the consumption of coal and other fuels, thereby contributing to efforts to reduce their usage.

8.2.4 Other Biomass Materials

The government of Odisha is focusing more on strengthening its renewable energy capacity utilisation and targeting the available biomass to be a suitable replacement for fossil fuels. The government of Odisha has harnessed its renewable energy potential, as reflected in the Renewable Energy Policy of Odisha, 2022, and is targeting to increase the renewable capacity to 10 GW by 2030. Apart from traditional non-fossil-fuel sources like hydro, solar, and wind energy, the policy document also considered non-traditional sources like green hydrogen, green ammonia, floating solar, biomass, waste-to-energy, etc. Despite having significant potential for renewable energy sources in Odisha, renewable energy's share in the power sector is only 1%[43].

In Odisha, various raw materials are readily available to produce briquettes. Abundant agricultural resources provide ample supplies of rice husk, groundnut shells, sawdust, paddy straw, bagasse, cotton stalk, bamboo dust, soybean husk, and sunflower stalk. These locally sourced materials support waste management and sustainable agriculture practices but also contribute to reducing the reliance on fossil fuels like coal. Briquettes are a cost-effective alternative to coal, offering several advantages regarding environmental impact. These briquettes offer an eco-friendly alternative, as they do not introduce pollutants to the environment upon combustion, thanks to their absence of sulphur content.

Figure 64: Briquettes manufactured from agricultural waste

43 https://orierc.org/(S(3eamlwojlkajvw04k3t2a33q))/UploadData/LatestUpdates/a84779f2-4b85-4778-b26d-109bd79da9a9.pdf

Moreover, they exhibit a superior practical thermal value and notably reduced ash content, thereby ensuring a combustion process that is not only cleaner but also more efficient. One of their standout characteristics is their ability to burn without generating fly ash, setting them apart from coal. Briquettes showcase superior boiler efficiency compared to firewood or loose biomass due to their low moisture and higher density[44].

Table 42: Raw materials available in Odisha can be used in biomass (CV values)

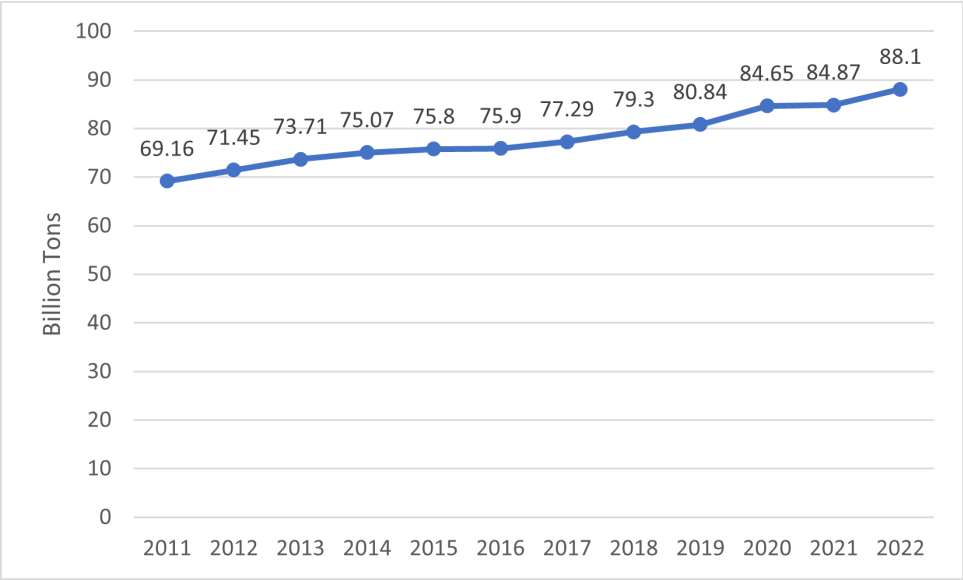
Raw material	Calorific value
Rice Husk	3900 Cal. Val. & Ash % 16.36
Groundnut Shell	4500 Cal. Val. & Ash % 3.80
Saw Dust	4400 Cal. Val. & Ash % 1.20
Paddy Straw	3469 Cal. Val. & Ash % 15.50
Bagasse	4700 Cal. Val. & Ash % 1.80
Cotton Stalk	4200 Cal. Val. & Ash % 3.01
Bamboo Dust	3700 Cal. Val. & Ash % 8 .00
Soyabean Husk	4170 Cal. Val. & Ash % 4.10
Sunflower Stalk	4300 Cal. Val. & Ash % 4.30

In Odisha, using briquettes has found extensive applications across various industries, contributing significantly to sustainable energy practices and environmental conservation. Briquettes are a cleaner and more efficient alternative to traditional fossil fuels like coal in solvent extraction plants, chemical units, dyeing plants, milk plants, and food processing industries.

8.2.5 Fossil Fuels

The state has witnessed a steady growth in coal availability. In 2011, the total coal extraction stood at 69.16 billion tons, which has now climbed to roughly 88.1 billion tons by the year 2022. The primary coal fields are situated in Anugul, Dhenkanal, constituting the Talcher Coalfield, and in Sambalpur, encompassing the Ib River Coalfield and Jharsuguda Districts. Additionally, less economically viable coal occurrences are identified within various basins, including Athgarh, Gaisilat, Athmallick, and Katrinjia basins.

Figure 65: Availability of coal in Odisha (Billion tons)



43 https://3.imimg.com/data3/WT/QW/MY-4635095/biomass-briquettes.pdf

8.2.6 Factors Affecting Availability (e.g., Location, Origin, Transport, Depletion)

Fly ash is supplied to Bhubaneswar from the TALCHAR thermal power plant in Angul, located approximately 160 km away, and is distributed to various parts of Bhubaneswar. Within a 300 km radius of the TPP, five cement plants (four in Odisha and one in Jharkhand) produce different types of cement like OPC, PPC, and PSC. These cement plants collectively possess an installed capacity of around 129.50 lakh tons per annum. Only the three cement plants in the Jharsuguda-Sambalpur-Bargarh belt of Odisha produce PPC. None of the cement manufacturers have outlined capacity expansion plans for the upcoming five years[45]. Cement manufacturing units are established within a radius of 15 to 20 Km. of limestone deposits.

Regarding fly ash bricks, many well-known brick manufacturers are situated within approximately 100 km of the TALCHAR thermal power plant area. Through field surveys, discussions, and insights gathered from Fly Ash Brick Manufacturers and their local associations, an estimated 150 independent Fly Ash Brick manufacturing units operate in this region. These units, with an average production capacity of 12,000 bricks per day, are primarily concentrated in Angul (around 65 units) and Dhenkanal (approximately 85 units) Districts, falling within the 100 km radius of the TSTPS. Notably, these units are spread out without forming any major clusters[46].

Most of the machines used for the manufacturing are manufactured in Vishakhapatnam of Andhra Pradesh and Raipur of Chhattisgarh. They are transported to various parts of Bhubaneswar as per the demand[47].

Table 43: Raw material requirement for cement plan

Source: M/s. Jajpur Cements Private Limited- updated form-i & pre-feasibility report,2018

Raw materials	Source	Transportation mode	Requirement
Clinker	Will be sourced from Sagar Cements plant, Nalgonda district, Telangana state.	Rail/Road	0.558 MTPA
Gypsum	Paradeep Phosphates Ltd. Paradeep	Road (Trucks)	0.060 MTPA
BF Slag	TATA Steel Ltd, Kalinga Naga	Road (Trucks/ Tractor/ trailers)	0.837 MTPA
Fly ash	MCL, Odisha	Road	0.045 MTPA
Coal	MCL, Odisha	Road	0.066 MTPA

8.2.7 Stock Vulnerability to Hazards and Climate Change

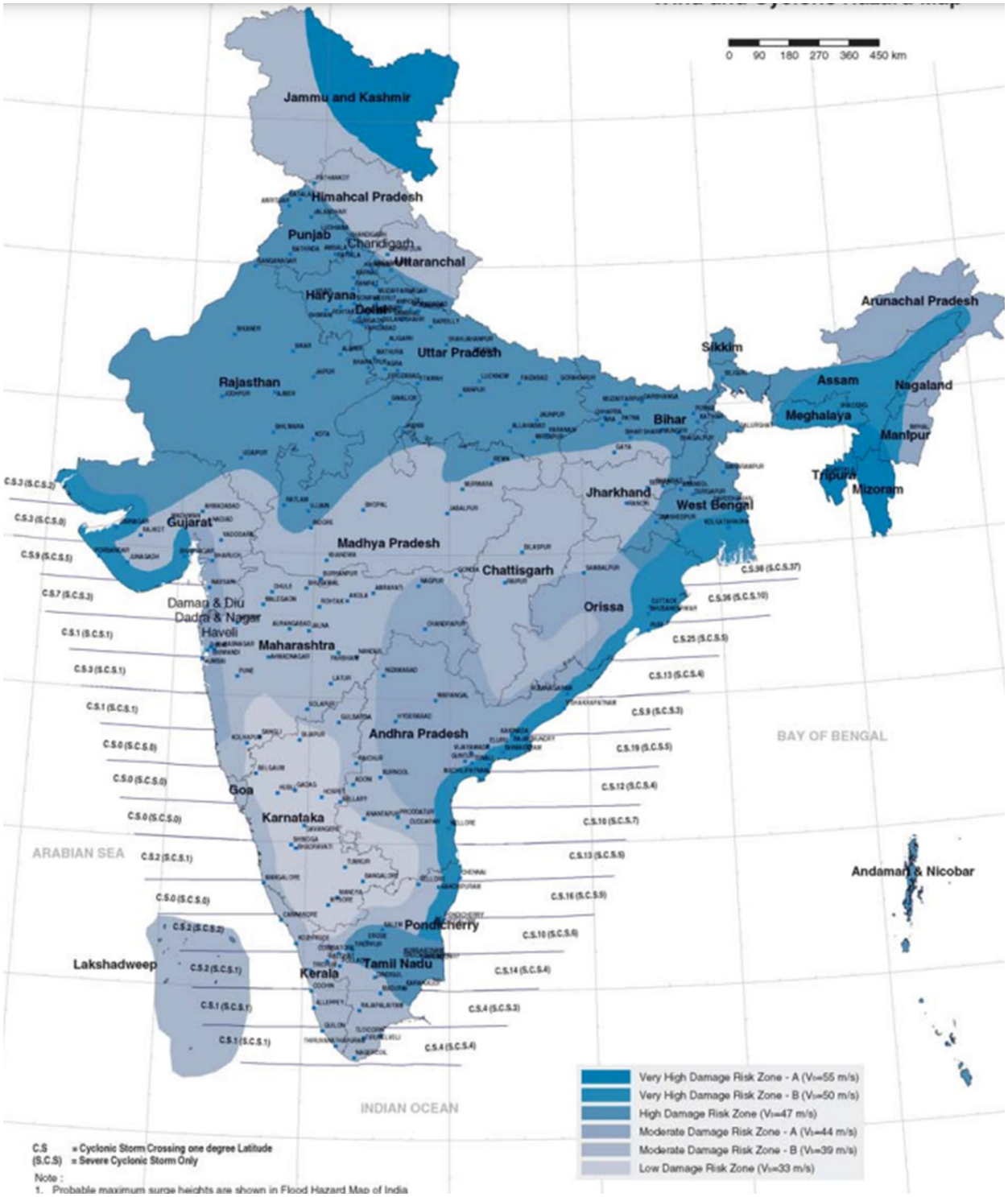
The East Coast of India is one of the six most cyclone-prone areas in the world among the four states situated at the head of the Bay of Bengal (West Bengal, Odisha, Andhra Pradesh, and Tamil Nadu). Odisha has experienced a large number of cyclonic storms. (BMTPC) Building Materials & Technology Promotion Council- Ministry of Housing & Urban Poverty Alleviation is working to develop proper guidelines. It is responsible for the revised publication of improving cyclone resistance of housing. There are various types of non-engineered buildings, particularly housing, traditionally built by people in cyclone-prone areas and other high wind velocity areas where severe damage occurs under wind hazard occurrences. It is important to provide special strengthening of the residences located in the cyclone-prone areas of Odisha by using standardised proportions of the cement - sand-mortar to reinforce the walls by means of reinforced concrete bands, and in the areas such as door-window lintel level, eaves level of pitched roofs, below flexible flat roofs, and top of external gable walls. The strengthening methods should be suggested based on further research using probable maximum wind speeds in cyclone-prone seacoast areas. The construction sector in such disaster-prone areas needs to be outlooked based on Various strategies that can be implemented, such as a lintel band provided at the lintel level on all load-bearing internal, external longitudinal, and cross walls.

45 https://environmentclearance.nic.in/DownloadPfdFile.aspx?FileName=QMZNbUh03FAY75UtAajRtoYIvaUDwvUjYPNK6r1gzBKv/xO6MPIfMvE+dDRUvJ0a0asb818WqCU2qUX5bgGJbKLptGle1fn/ce5KL+iAyz0DIe3pqk6puU+Ppw/fUkkvnR/8nkCDad6tFQexMFBiO1Weifq3/eW2P9TrR/cgrYTJlvCigZrBAFA70kp8xPwh&FilePath=93ZZBm8LWEXfg+HAlQix2fE2t8z/pgnoBhDlYdZCxzXmG8GlihX6H9UP1HygCn3plxj9Obixc3BWfxB07ZTvXQ==

46 https://cutm.ac.in/wp-content/uploads/sdg/pdf/DIAGNOSTIC-STUDY-FLY-ASH-CLUSTER_Koraput.pdf

47 https://environmentclearance.nic.in/writereaddata/Formb/MODITOR/06012018567TC4OFJCPLFORM-I&PFR.pdf

Figure 66: Risk zones of India based on disaster



Material Selection

The selection of Building materials is the biggest challenge for building houses in disaster-prone areas. A load-bearing brick masonry structure may be adopted. All stilted shelters should be raised on an RCC frame, and the upper portion could be constructed with load-bearing brick masonry. To lessen the weight on foundations, lightweight pre-cast concrete blocks (hollow concrete or aerated fly ash mixed concrete) might be considered for non-load-bearing infill and partition walls. Rat-trap bonds can be used with solid bricks to reduce weight and brick usage by roughly 25%. The reinforcement in the structure should be done using corrosion-resistant materials, as corrosion-resistant steel results in a durable structure. All the materials should conform to the relevant IS Codes.

8.2.8 Traditional Construction Materials and Construction Elements (Identification of Main Ones and Processes)

Construction practices and technologies in Bhubaneswar, Odisha, have evolved over the years, ranging from traditional practices to upgraded contemporary materials. The major influence to adapt shift in construction technologies from ancient to modern and under research materials is based on the region's unique climatic conditions, cultural influences, temple architecture, and the locally available resources. The traditional construction techniques were based on the rich cultural influences that have been in use for centuries. These techniques often involve low-rise buildings using locally available materials based on climatic conditions, such as using materials that are effective for the occupants in warm and humid climates. The buildings were made of locally available materials like stone, mud, timber, and bamboo. Traditional houses in rural areas often feature mud walls with thatched or tiled roofs. The old house has a sloping roof that quickly sheds heavy rain and protects walls from getting damp and absorbing heat from the sun. Some windows have been replaced with jalis, which are cheaper and give permanent ventilation, light, and protection (Kulshreshtha et al., 2020).

Figure 68: Different types of roofing materials (a) Thach roof (b) Bamboo roof (c) Sundried clay roof

Figure 67: Walling Materials used in vernacular buildings (a) Mud Walling (b) Sundried Bricks (c) Laterite stone wall

The current practices followed in Bhubaneswar for the construction based on the various structural elements are- The total width of openings in a load bearing or shearing wall should not exceed 50% of the length of the wall, no opening should be located within 2 times the wall thickness or one-twelfth of the storey height whichever is less, from the cross wall. Reinforced concrete, steel, or timber framing can be used as an alternative to vertical load-bearing walls. The frame comprises rigidly connected beams and columns or posts in RCC constructions. In steel and timber constructions, complete structural framing should be adequately braced in vertical and horizontal planes. In the case of a thatched roof, it should be properly tied to wooden framing underneath using organic or nylon ropes in a diagonal pattern. The foundation wall and roof bonding should be tight, and bracings or more concrete bands should be provided in the structure. Adopting improper construction practices in such disaster-prone areas may lead to failures in many cantilever structures and damage to improperly attached windows or window frames, roof projections, chajjas, and sunshades. Overturning failures occur most of the time of compound walls of various types, and consequent failure of roofs and roof covering, failure of roofing elements and walls along the gable ends, particularly due to high internal pressures.

8.2.9 Industrialised Materials (Identification and Processes)

Odisha is one of India's largest industrial hubs, generating around 50% of the industrial products. The large production of goods leads directly to the huge production of industrial waste (Bhawan et al., 2020).

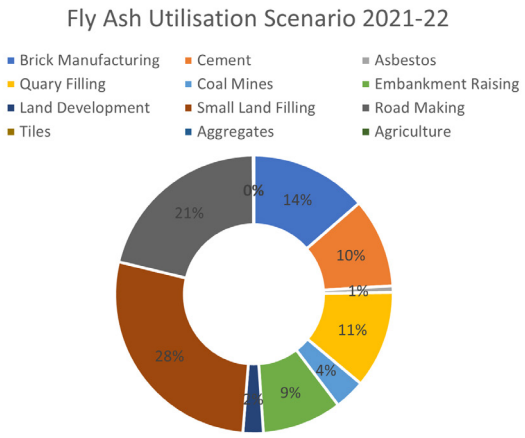
Table 44: Industrial waste generated in Odisha

S. No.	Category of the Industry	Type of solid waste	Quantity generation (In Million Ton/ Annum)	Technology adopted for Utlisation/Disposal
1	Coal-based power plants	Fly ash	41.22	90% (37MTPA) utilised in mine void/ quarry void filling, fly ash brick making, asbestos making, cement making, road making, and Land development.
2	Fertiliser plants	Phospho-gypsum	6	19% utilised for soil conditioning, fly ash brick making and cement making
3	Aluminium refineries	Red mud	8.18	Stored in properly designed red mud ponds.
4	Sponge Iron Plants	Dolochar & Dust	15.33	Mostly dumped along with the dust in the earmarked area and covered with soil. Part of Dolochar is utilised in FBC boiler for power generation.
5	Blast Furnace of steel Plants	slag	14.88	100% utilisation in Cement plant
6	Steel Melting Furnaces & ferro alloys plant	slag	11.37	Utilised in the landfilling, road making, and dumping on earmarked areas.
		Total	96.98	

Fly Ash

Fly ash, a by-product of coal combustion in thermal power plants is extensively used throughout Odisha to manufacture bricks. These fly ash bricks offer advantages such as reduced environmental impact, improved thermal insulation, and enhanced strength compared to traditional clay bricks. [48]Odisha has approximately 40 thermal power plants that generated around 33.16 million tonnes of fly ash in the financial year 2021-22. Out of the total fly ash generated, 90% is effectively utilised. The alternate modes in which fly ash is currently being utilised are manufacturing of the building materials- Bricks, cement, Asbestos, tiles, aggregates; coal mining landfilling; road making; Quary Filling; Land Development, etc. *(Diagnostic Study of Fly Ash Brick Cluster in Koraput, District of Odisha, n.d.)*

Figure 69: Fly Ash utilisation scenario 2021-22



48 Industrial waste Department, OSPCB 2021-22 Data

More than 80% of the total fly ash is utilised in Odisha, out of which almost 50% is used in the construction sector, which is the reason for the widespread use of fly ash bricks in Bhubaneswar and other cities where fly ash is readily available. This is a successful example of policy implementation that replaces virgin resources with secondary wastes like fly ash and resource efficiency in the construction sector. The policy also shaped the market economics of fly ash bricks by promoting the use of a complementary waste material available in abundance.

Figure 70: Quantity of fly ash generated and utilised in Odisha 2015-2022 (In Million tons)

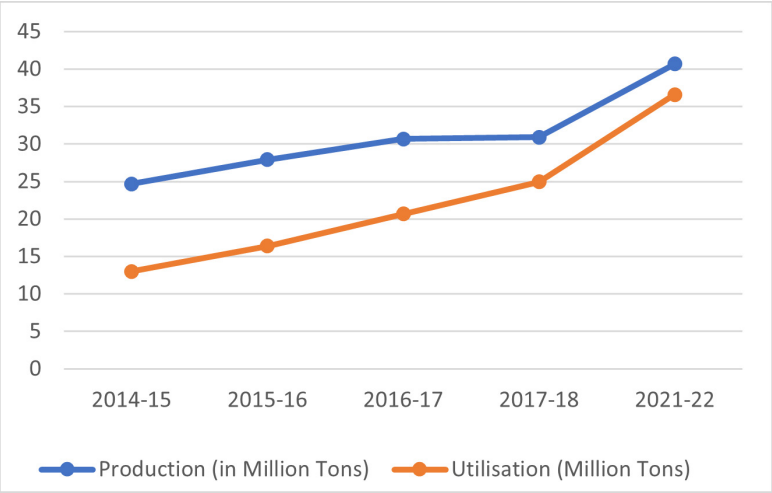
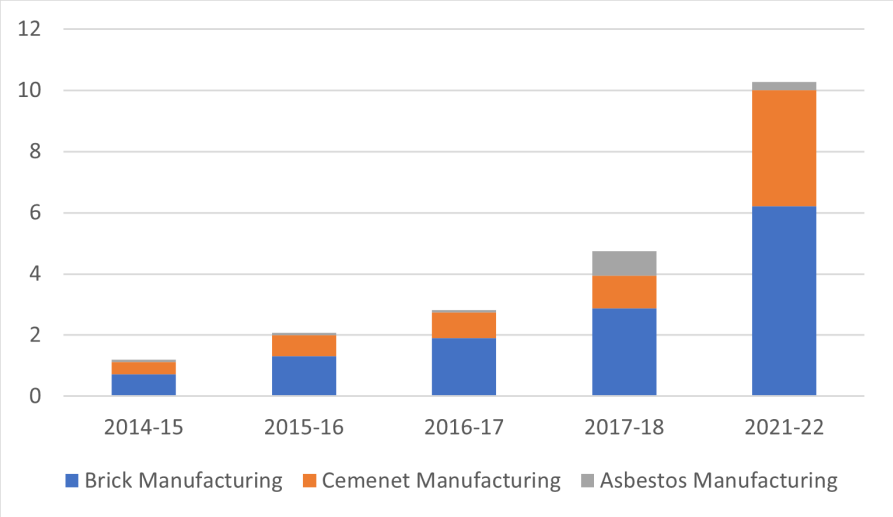


Figure 71: Quantity of fly ash utilised in brick, cement, and asbestos (In Million tons)



Red Mud

Red mud is a waste from the alumina industry, and its disposal and utilisation have always been a concern for environmentalists and industry. The red mud is collected from a pond in a sundried state. Several attempts have been made to recycle red mud to avoid environmental pollution and to use it in developing polymer composites, wood substitute products, bricks, ceramic glazes such as porcelain, and sanitary ware glazes.

Figure 72: Formed blocks from red mud

CSIR-IMMT and IIT Bhubaneswar have researched on red mud to utilise it as a building material that can be used to replace a certain percentage of raw materials. Vedanta has suggested replacing 20% of the sand in concrete or 15% of cement replacement using the red mud in concrete. By replacing a portion of sand with red mud in concrete, the research contributes to sustainable construction practices.[49] NALCO (National Aluminium Company Limited) research explores the potential of utilising red mud, fly ash, and slag to produce non-cement-based concrete, known as geopolymer concrete. Geopolymer concrete is an innovative alternative to traditional cement-based concrete with several environmental and technical advantages. Diverting these waste materials from landfills reduces the environmental impact and promotes sustainable waste management practices *(Guidelines for Handling and Management of Red Mud Generated from Alumina Refineries,* n.d.). [50]

Figure 73: Red mud

Red Mud-generating Zones

Bauxite deposits of Orissa are of diverse parentage. More than 95 percent of the bauxite resources of the state come under East Coast Bauxite (Eastern Ghats Mobile Belt) located in the Southern and Western parts of the state, i.e., Koraput, Raygada, Kalahandi, and Bolangir districts.

Management and Disposal Practices of Red Mud

M/s Utkal Alumina International Ltd., Odisha

There are 4 ponds, of which 3 are operational. Pond A was initially designed for wet storage and has been used for dry mud stacking since June 2017. Filter Press is used, and dry stacking of Red Mud is being followed.[51]

M/s Vedanta Limited, Lanjigarh, Odisha

High-concentration slurry disposal of red was followed till 2013. After 2013, High-Pressure Membrane Filtration Technology has been used for dry stacking of Red Mud. The filter-cake Red Mud is transferred to the pond via truck, spread in lifts to dry with a dozer, and compacted with a sheep roller.

M/s NALCO Ltd., Damanjodi, Odisha

The Thickened Tailing Disposal (TTD) System is used wherein the Red Mud is discharged into a pond (RMP) at solid consistency varying between 54% - 60% at one point for having a sloped deposit. Installation of the Filter Press is under Process.[52]

49 https://www.adityabirla.com/businesses/companies/utkal-alumina-international-limited

50 https://www.hindalco.com/upload/pdf/utkal-alumina-ec-compliance-staus-october20-april21.pdf

51 https://ospcboard.org/wp-content/plugins/hearing/uploads/files_1503400723_303527866.pdf

52 https://cpcb.nic.in/openpdffile.php?id=TmV3c0ZpbGVzLzg5XzE2Mjg3NTEwNDhfbWVkaWFwaG90bzIzMDk2LnBkZg==

Table 45: Annual red mud generation in Odisha

Name of the plant.	Quantity of red mud generated based on the annual generation[53] (Metric Tonne)			
	2015-16	2016-17	2017-18	2018-19
M/s Utkal Alumina International Ltd., Odisha	1914000	1974000	2049000	2082000
M/s Vedanta Limited. Odisha	1497733	1626194	1694693	1758462
M/s NALCO Ltd., Odisha	2789160	3137853	3096637	3057509

8.2.10 Agricultural Materials (Identification and Processes)

Odisha is primarily an agrarian economy, having nearly 21.11% contribution to India, with 73% of the workforce engaged in the agriculture sector. The cropped area is about 87.46 lakh hectares, of which 18.79 lakh are irrigated. The total cultivable land used for cropping is about 40% of the total geographical area, and the utilisation is comparatively more in the coastal districts of Odisha. Odisha is one of the largest producers of rice in India. The main crops cultivated in the state are rice, jute, oil seeds, pulses, coconut, Mesta, roselle, sugarcane, tea, turmeric, rubber, cotton, gram, mustard, maize, sesame, ragi, potato, and soybean. With almost 60 % of land under rain-fed agriculture and water-dependent rice as its main crop, the agriculture sector is particularly vulnerable to climate change (Biomass-Briquettes (2), n.d.).

Utilising Agri Waste as a Building Material

As one of the largest rice producers, the state generates enormous rice husks. Its management has become a massive problem for the state. Various professors are working in this sector to utilise agricultural waste to produce building materials depending upon the properties of the raw materials.

Table 46: Quantity of rice produced

Year	Quantity of Rice produced (Million Tonnes)
2011	6.83
2012	5.81
2013	7.3
2014	7.61
2015	8.3
2016	5.8
2017	8.3
2018	6.55
2019	7.73
2020	8.36
2021	8.81

Rice Husk Ash

Rice Husk Ash (RHA) is also available in Odisha in massive quantities. One of the most promising applications of RHA is in the manufacture of lightweight concrete. Research in this application could directly benefit manufacturing lightweight concrete blocks, which are gaining popularity in Bhubaneswar. For every ton of rice processed, an average mill produces 200 kg of rice husk and 40 kg of RHA. Thus, the total amount of rice husk produced in India is about 24 million tons, while the RHA production is around 4.4 million tons annually. Rice Husk Ash is in the steel, cement, and refractory bricks industry. Based on the recent data available, the total amount of rice production in 2021 was 8.81 million Tones, which can produce around 0.35 Million tonnes of Rice husk ash.

53 https://cpcb.nic.in/openpdffile.php?id=TmV3c0ZpbGVzLzg5XzE2Mjg3NTEwNDhfbWVkaWFwaG90bzIzMDk2LnBkZg==

54 https://www.researchgate.net/publication/267824760_Waste_to_Wealth_-Potential_of_Rice_Husk_in_India_a_Literature_Review#:~:text=For%20every%20ton%20of%20paddy,tons%20per%20year%20%5B9%5D%20.

8.3 Material Transportation

8.3.1 Import/Export and Internal Transport

Transportation accounts for 3-4% of the total emissions from residential construction, including transport of primary materials into the city and transport to construction sites within the city. Overall, every m2 of built space accounts for 70-80 km of material transport, of which masonry materials and cement account for 60-65% and 15-20%, respectively.

Cement- A few major cement plants supply cement to Bhubaneswar- the bulk is sourced from plants in Tangi-Chowdwar in Cuttack district. Another significant source is Rajgangpur in Sundargarh. Generally, the transportation distance is 200-300 km from the cement plant to the Railhead and to the distributor in Bhubaneswar.

Sand is transported over 30-40 km from rivers Daya, Mahanadi, and Kuakhai, a Mahanadi distributary.

Coarse aggregates are sourced from 50-100 km. The stone-crushing plant in Chandikhol in Jajpur district is a primary source, 75 km from Bhubaneswar.

Fly ash bricks are sourced from within a 50 km radius of Bhubaneswar. The nearest source of Fly ash in the state is NTPC Angul, 150 km from Bhubaneswar.

Steel is sourced from various steel plants – the Jindal plant in Angul 150 km away, the RINL plant in Visakhapatnam 350 km away, the SAIL plant in Rourkela 350 km away, and the TATA plant in Jamshedpur 350 km away. The average distance of transportation of steel is 250 km.

8.3.2 Costs of Transport

The expenses associated with transporting various raw materials are determined on a per-ton basis, considering the distance between the source of the material and the manufacturing facility. To illustrate, the conveyance of fly ash to Bhubaneswar originates from TALCHAR Angul, which lies approximately 140 km away from the manufacturing sites of fly ash bricks and AAC blocks in Bhubaneswar. It's worth noting that thermal power plants provide fly ash without any charge, thereby entailing only the transportation cost, which is factored into the supply of fly ash. The TALCHAR thermal power plant, positioned roughly 120 km from Bhubaneswar, levies an approximate fee of 700 Rs. per ton for transportation. [55] Similarly, other thermal power plants, such as Arti Steel and Power, about 80 km from Bhubaneswar, impose a transportation fee of around 500 Rs. per ton for fly ash supply.

Conversely, the cost of transporting fly ash from NTPC Kania, located much farther at 120-150 km from Bhubaneswar, amounts to 1100 Rs. per ton. The prevalent mode of transportation for fly ash across Odisha is through bulkers. It's pertinent to mention that many manufacturers opt not to own transportation vehicles but prefer leasing vehicles for transportation purposes. The transportation of gypsum is 400 Rs. per Ton for manufacturing the fly ash bricks. Sand is supplied from Mahanadi; the nearest point is around 60-70 Km from Bhubaneswar. The cost of transportation Is Rs. 5500 per truck, which is approximately 20 tons in size. Cement transportation is done at Rs. 25.25 per bag, approximately 50 Kg. The cost of one truck of lime is Rs. 2400/- but the transportation cost is relatively high. The normal size of the brick is 3 X 4 X 9 inches in nature. The producers used to pay Rs. 125/- for making of 1000 number of bricks. The transportation of Mild steel is Rs. 500-550 per tons and is supplied at 16-18 tons capacity.

55 https://www.hindalco.com/upload/pdf/utkal-alumina-ec-compliance-staus-october20-april21.pdf

8.4 Environmental Degradation and Pollution

8.4.1 Regeneration and Renewable Practices

Odisha has a good potential of generating renewable energy based on solar, biomass, and small hydro capacities. As of now, no wind capacities are installed in the state. The current installed renewable energy capacity in Odisha (utilities only) is around 520 MW. Most of Odisha's areas neighboring Andhra Pradesh have good wind energy potential at 120 m hub height generation.[56] However, frequent cyclones are one of the reasons that have deterred developers till now from harnessing the potential for electricity generation.

Figure 74: Renewable energy potential in Odisha

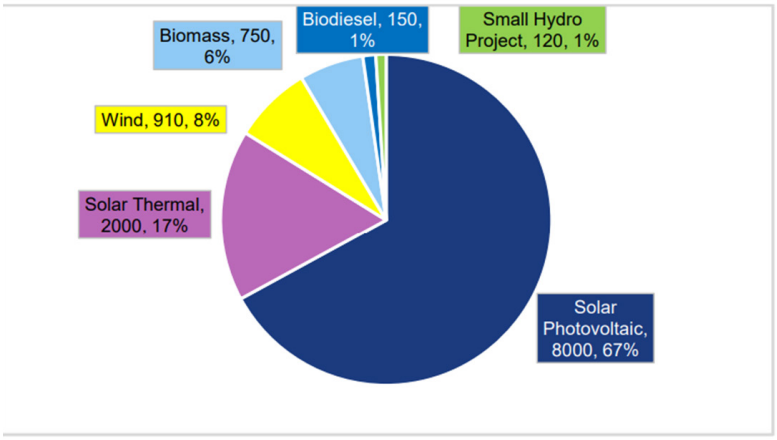
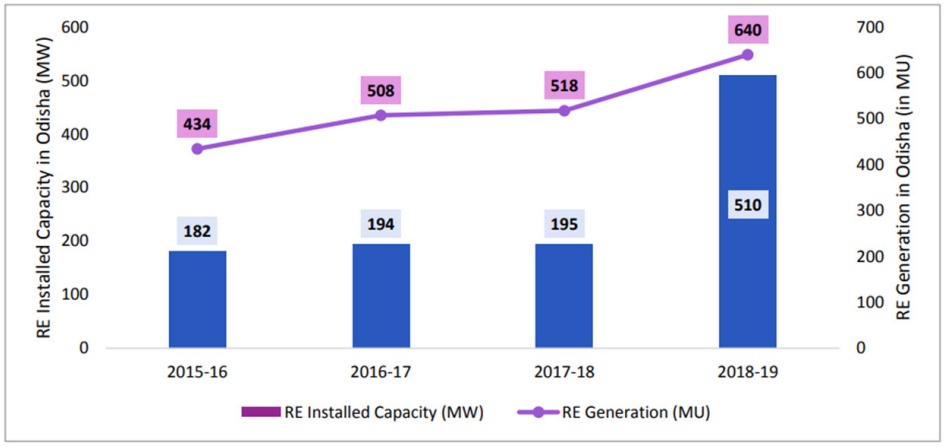


Figure 75: Installed capacity and generation in Odisha, 2019

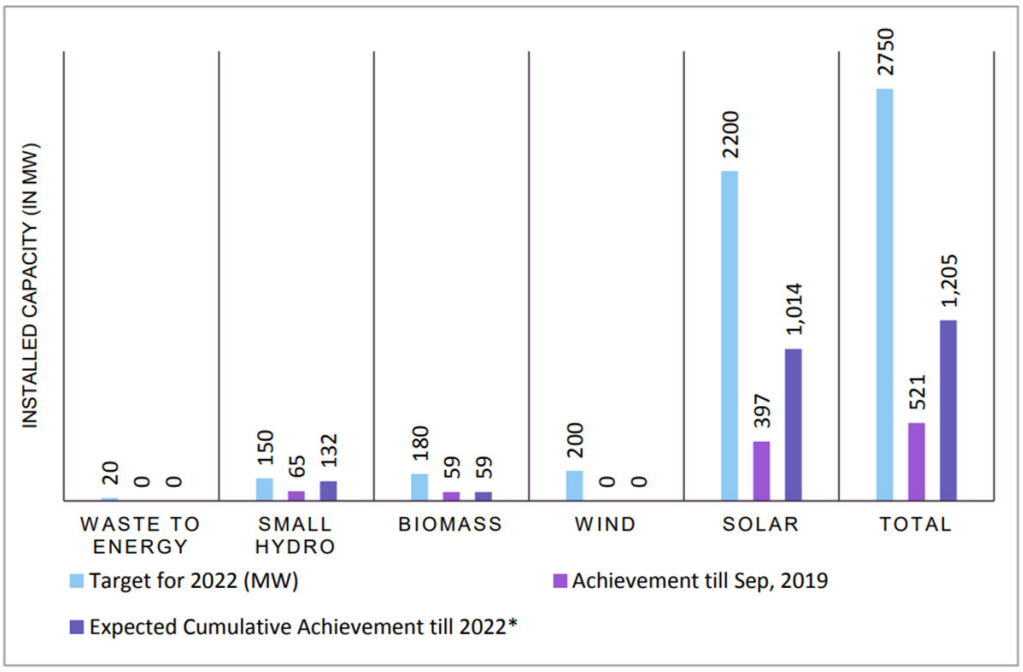


As per OREDA, the total Gross RE potential in the state is around 53,820 MW, of which around 11,820 MW is the feasible potential. Odisha has currently realized only 4% of its RE potential. Some RE stakeholders believe that the actual potential of solar and wind energy is lesser than the estimated value. According to an OREDA official, the potential has been estimated based on the assumption of land availability of 2 percent. Still, the actual land availability is far lesser because of substantial forest and agricultural land in the state. [57]

56 https://vikaspedia.in/energy/policy-support/state-wise/odisha

57 https://irade.org/Discussion%20Paper%20Power%20Sector%20Report%20Odisha.pdf

Figure 76: Technology-wise target, achievement until September 2019



Odisha has an installed capacity of 12,322 MW as of December 2022 (CEA), of which 9,540 MW of installed capacity is for coal-based power plants. So, emission in Odisha is largely driven by high dependence on coal (90%) as a source of power generation in the state (in 2021-22). Other sources of power generation are hydro (8%), small hydro (1%), and solar (1%). Odisha is one of India's few states with a surplus in electricity production: only 33% of the produced electricity is consumed within the states, and the rest is exported to other states. Selling electricity is a source of revenue for the state. Revenue from Taxes and Duties on Electricity in Odisha was Rs. 393846.21 lakh in 2020-21.[58]

For renewable energy development, major challenges are land acquisition and opportunity costs involved with RE development. Odisha's renewable energy-rich sites are mainly in forest areas or agricultural land, so it is quite difficult for the state to establish a large-scale solar power sector. Despite having significant potential for renewable energy sources in Odisha, renewable energy's share in the power sector is only 1%. The pragmatic alternative is to continue with coal-based electricity but adopt the latest technology to reduce emissions.

8.4.2 Diversion from Landfills

Bhubaneswar produces around 200 metric tonnes of C&D waste daily, disposed of in the dumping yard at Patia (Khorda district) and Kargil Road.[59] The city has no initiative to utilise C&D waste, although there is a plan to set up a C&D plant in Bhubaneswar soon.[60] Acknowledging the need to adequately manage the C&D waste generated by the city of Bhubaneswar, GIZ, in collaboration with the Ministry of Housing and Urban Affairs (MoHUA) through the Climate Smart Cities (CSC) project, carried out interventions to identify and address this concern. The generated waste primarily comprises waste streams, including majority fractions of soil and masonry construction material such as brickbats. To assess the current state of the C&D waste cycle in Bhubaneswar, the following areas are looked at: the issuance of a Building Planning Permit, Management, transportation, and disposal on-site. The waste generated by construction activities varies depending on the building activity type and typically comprises broken bricks, tiles, concrete waste, excavated earth, debris, and wood waste. To manage on-site demolition waste, contractors first remove or disassemble salvage items from buildings, such as electrical lines, doors and windows, truss roofed structures, steel trusses, reinforcement steel, etc. These materials are utilised in new construction or sold in the secondary market. There is a separate market for reusable building supplies, and such businesses have partnerships with demolition firms.[61] PWD, BDA, Odisha Housing Board, and commercial large-scale infrastructure businesses and demolition contractors are among those identified. There is currently no initiative in the city to utilise C&D waste, although there is a plan to set up a C&D plant in Bhubaneswar.

58 https://www.ncaer.org/news/the-way-forward-for-odisha-power-sector
59 https://csc.urban-industrial.in/hrdpmp/igep-uid/content/e5170/e6258/e14274/e15776/ConstructionandDemolitionWaste_Brochure.pdf
60 District Environmental Plan Khorda, 2022
61 https://urban-industrial.in/hrdpmp/igep-uid/content/e5170/e6258/e14274/e15776/ConstructionandDemolitionWaste_Brochure.pdf

Figure 77: Erstwhile Nandan Vihar C&D waste dump yard, Bhubaneswar

8.5 Innovative Materials

In Bhubaneswar, like many other cities, there has been a growing interest in adopting new and advanced building materials that offer improved performance, sustainability, and efficiency. Some of the notable new and advanced building materials that are currently being utilised in Bhubaneswar include:

Table 47: Innovative building material and the percentage of emissions reduction

Innovative Building material	Replacement of	Emission in innovative material	Composition
Sintered Fly ash aggregates	Aggregates	Reduction of emission by 30-40%. [62]	90-95%, highest in any fly ash-based product with cement 2-5% and water
Fly ash bricks	Clay Bricks	Reduction in emission by 70-80% than clay bricks. [63]	60% of fly ash is utilised per brick
Autoclaved Aerated Concrete blocks (AAC)		AAC Blocks consume approx. 70% less energy than Clay bricks. [64]	Complete Replacement of sand and cement by a few percentages. [65]
Geopolymers	RMC (ready mix concrete)	Reduction in emission by 40-55%. [66]	Recycled aggregate concrete (RAC) combines 50% GGBS with 50% Portland cement, but percentages of GGBS can range between 20 and 80 %.
Red Mud	Cement and sand replacement		Replacement of Cement and sand by 10-15%
LC^3	Cement	Reduction of emissions by 30-40% during the production process.	50% clinker 30% limestone 5% gypsum 15% calcined clay

62 https://www.sciencedirect.com/science/article/abs/pii/S0959652622026543

63 https://www.researchgate.net/figure/Comparison-of-cost-and-CO2-emission-between-clay-fly-ash-bricks_tbl2_308398895

64 https://www.ijert.org/research/burnt-clay-bricks-versus-autoclaved-aerated-concrete-blocks-IJERTV3IS110454.pdf

65 https://theconstructor.org/building/autoclaved-aerated-cement-blocks-aac-properties-advantages/37211/

66 https://www.researchgate.net/publication/251624337_Costs_and_carbon_emissions_for_geopolymer_pastes_in_comparison_to_ordinary_Portland_cement

Precast construction technology- Precast construction technology creates elements such as precast walls, slabs, beams, etc. These factory-produced components are cast on-site and are placed after they are manufactured. It offers benefits like high strength, durability, faster construction speed, and enhanced quality control. There is a need for a more balanced and innovative approach towards prefab building elements, increasing construction's resource efficiency. There are proven technologies in small-scale pre-casting of concrete, primarily for roof construction, which reduce steel consumption by 15-20%. For instance, using a precast plank and joists or precast ferrocement roofing elements reduces the steel consumption by 10-12% per sq.m. of roof constructed. Using precast concrete roofing elements in 1 Lakh affordable houses (considering an average area of 40 m^2) will save 6.5 million tonnes of steel, resulting in a CO_2 emission reduction of 18.2 million tonnes.[67]

Figure 78: Precast construction technique practice under EPC model of affordable housing in Bhubaneswar

Fly ash Bricks- Fly ash, a by-product of coal-fired power plants, has replaced the usage of clay brick in the entire state. These bricks are known for their strength, thermal insulation properties, and environmental sustainability. In Bhubaneswar, using fly ash-based bricks and blocks for wall construction has significantly reduced carbon emissions by 40-45% compared to traditional clay bricks. However, Odisha has approximately 40 thermal power plants that generated around 33.16 million tonnes of fly ash in the financial year 2021-22. Only a small fraction of about 17% is utilised in the brick sector. However, the government is actively exerting pressure to increase the utilisation of fly ash in the brick-making sector and promote its wider adoption.[68]

Figure 79: Use of fly ash bricks in PPP model of affordable housing

AAC Blocks- Autoclaved Aerated Concrete (AAC) blocks are lightweight, precast building blocks made from a combination of sand, cement, lime, and aluminium powder. AAC blocks consist of fly ash (60-65%), water, quick lime (20%), cement (10%), aluminium powder, and gypsum (5%). The lightweight nature of AAC blocks makes them particularly suitable for affordable housing projects. They are commonly used for creating partition walls in the EPC (Engineering, Procurement, and Construction) model of affordable housing projects. These blocks contribute to the overall cost-effectiveness of such projects while providing the necessary structural integrity and insulation properties. AAC blocks have also gained recognition as certified green building material due to their eco-friendly characteristics. By utilising fly ash, the construction industry can reduce the demand for cement and minimise carbon emissions, contributing to a more sustainable building sector. Due to the replacement of cement with fly ash, the carbon emission is reduced by 22.38% at the manufacturing stage.

67 DA- GIZ Bhubaneswar report, June 2020

68 OSPCB, Industrial waste department 2021-22

Figure 80: Use of AAC blocks (fly ash based) in partition wall of EPC model

Glass Fiber Reinforced Gypsum (GFRG) Panels: GFRG panels are prefabricated panels made from a mixture of gypsum plaster and glass fibers.[69] They offer excellent fire resistance, structural strength, and sound insulation properties. In various construction projects, GFRG panels are used for walls, partitions, and roofing systems. To avoid the risk of the breakage of panels or the development of every third cavity of the building walls, it should be filled with M20 concrete and reinforced at a minimum. The remaining empty cavities should be filled with quarry dust mixed with 5% cement and water. The reduction in carbon emission attained by substituting concrete solid blocks with GFRG wall panels at the manufacturing stage is 45.7%.[70]

Figure 81: Glass Fiber Reinforced Gypsum (GFRG) panels for creating thermally insulated partition walls

These are a few examples of the new and advanced building materials utilised in Bhubaneswar. As the construction industry continues to evolve and emphasise sustainability, more innovative materials and technologies are expected to be adopted in the city's building projects. To address the significant emissions associated with transportation, priority should be given to locally available materials to minimise their carbon footprint. Research studies consistently indicate that the transportation of raw materials is a primary factor contributing to embodied carbon in construction. Therefore, emphasising locally sourced materials can help reduce these emissions and promote more sustainable building practices.

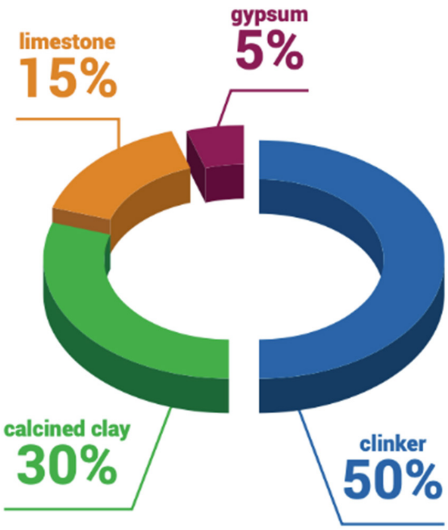
Limestone Calcined Clay Cement (LC^3) Cement

LC^3 incorporates a combination of limestone and calcined clay as its main constituents, with smaller amounts of gypsum and additional pozzolanic materials. Various research has shown that the carbon emissions from LC^3 production can be up to 40% lower compared to OPC. Using calcined clay as a substitute for a portion of the clinker in cement production contributes to this reduction, which is highly effective for resource efficiency. LC^3 cement has excellent potential to reduce the cement industry's clinker consumption and its environmental footprint.

69 https://krishisanskriti.org/vol_image/25Oct2019061023zz01%20%20%20Saqib%20Rashid%20%20%20%20%20290-294.pdf

70 https://www.irjet.net/archives/V5/i4/IRJET-V5I41057.pdf

Figure 82: Composition of LC³ cement



Geo Polymer

Geopolymer is no longer viewed as a concept for a greener society but rather as a pragmatic solution for reducing CO_2 emissions in the construction and building sectors. Using geopolymer as a potential cement alternative in construction has been shown to reduce the overall CO_2 emission by 9% to 64%, depending on geographic location, transport scenarios, activator production process, and mix design. The contribution of CO_2 emission to global warming stands at 65%, and producing one tonne of ordinary Portland cement (OPC) emits one tonne of CO2 into the atmosphere. (Sikder et al., 2022)

Figure 83: Geopolymer concrete

According to research findings, producing one ton of Ordinary Portland Cement (OPC) results in one ton of carbon dioxide emission. However, investigations into Geopolymer Concrete, which is made using Fly Ash and GGBS (Ground Granulated Blast Furnace Slag), have demonstrated significant reductions in carbon emissions. Specifically, Geopolymer Concrete has shown a carbon emissions reduction of 43% when compared to OPC-based concrete. Additionally, the use of Fly Ash and GGBS in Geopolymer Concrete has led to a carbon emissions reduction of 32% compared to OPC-based concrete.[71]

In Bhubaneswar, the construction industry is embracing innovative and sustainable building materials and technologies to address environmental concerns and enhance resource efficiency. Precast construction technology, known for creating factory-produced components like walls, slabs, and beams, offers advantages such as high strength, durability, and faster construction, contributing to overall operational energy reduction. Small-scale pre-casting of concrete, particularly for roof construction, has demonstrated a 15-20% reduction in steel consumption, showcasing the potential for resource-efficient practices. Fly ash bricks, replacing traditional clay bricks, have substantially reduced carbon emissions in wall construction

71 https://www.researchgate.net/publication/366987393_Geopolymer_Concrete_as_a_Revolutionary_Green_Building_Material_for_Modern_Infrastructures/link/63bd3c9903aad5368e7d85f0/download

by 25-30%, emphasising the need for increased utilisation of fly ash from thermal power plants. AAC blocks, composed of fly ash, contribute to cost-effective and eco-friendly construction, reducing carbon emissions by 22.38% during manufacturing. Glass Fiber Reinforced Gypsum (GFRG) panels, offering fire resistance and structural strength, achieve a significant 45.7% reduction in carbon emissions compared to concrete solid blocks. The adoption of locally sourced materials in construction is crucial to minimising carbon footprints associated with transportation. Furthermore, advanced cement options like Limestone Calcined Clay Cement (LC^3) and Geopolymer, which incorporates fly ash and GGBS, exhibit remarkable reductions in carbon emissions, with LC^3 potentially lowering emissions by up to 40% compared to Ordinary Portland Cement (OPC). Geopolymer concrete, in particular, showcases a noteworthy 43% reduction in carbon emissions, further highlighting the industry's commitment to sustainable practices in Bhubaneswar.

A Low Income Group Housing project

9. Conclusions and Outlook

The baseline assessment of the buildings and construction sector in Odisha, specifically for affordable housing, reveals several gaps and barriers inhibiting the uptake of sustainable building materials. At the same time, it is evident that several opportunities exist that can be leveraged to align state-level mandates for meeting housing needs with decarbonisation and circularity approaches. Coordinated efforts will be required across sectors and scales to enable a systemic transformation in the markets for sustainable building materials, including both demand and supply side mechanisms.

Summary

Some of the key challenges and opportunities emerging from the assessment are summarised in this section based on the three thrust areas of policy frameworks, market and finance, and materials and technology.

Policy Frameworks

Affordable housing clearly ranks as a key priority for the Odisha state government, and this is visible in its flagship Jaga Mission targeted at urban slum redevelopment, and other initiatives such as the OUHM, BPGY, and NSPGY. However, the state has yet to integrate sustainable materials adoption and resource efficiency strategies in the affordable housing policies and programs.

At present, tender specifications and BOQs for affordable housing development do not include any criteria for the environmental performance of the buildings or benchmarks for embodied or operational carbon, thereby allowing for the continued use of conventional materials with high carbon and resource footprints. Alternative materials such as sintered fly ash aggregates, products made from construction and demolition waste, etc. are available in the state. However, due to a lack of integration in the Schedule of Rates, and a lack of relevant quality control mechanisms, codes and standards, these materials are not being utilised in construction activities. While it is compulsory for government buildings and offices in the state to comply with the Energy Conservation Building Code, affordable housing development is not mandated to adopt energy conservation measures or align with other green building certification guidelines.

With CITIIS being renewed for the 2nd phase under the Smart City Mission, there is potential to leverage existing CITIIS initiatives in Odisha to provide affordable green housing through a combination of interventions aiming at enhancing the social, urban, and financial inclusion of low-income settlements.

According to the 2021-22 SDG India Index, Odisha ranked 22nd with top performance in SDG 13 (Climate Action) and 14 (Life under water). Including the embodied energy impacts of building materials in the state's climate strategies can help the state strengthen its performance further and establish benchmarks for other states. Moreover, the project through various cross-sectoral interventions has the potential to improve Odisha's performance across SDGs 8, 9, 11, 12 and 13.

Market and Finance

The market ecosystem in Odisha for affordable housing and sustainable materials needs to be strengthened to attract key stakeholders. For instance, the Odisha government has implemented the PPP model for affordable housing projects in Bhubaneswar, with a sharing ratio of 60 per cent for development for commercial sale and 40 per cent for affordable housing units. However, the unit economics and revenue models of this model are not considered lucrative enough by developers, thereby discouraging private builders from entering the field of housing for the EWS and LIG classes.

Concurrently, there is a severe lack of market mechanisms that enable the adoption of sustainable materials, such as financial incentives and subsidies supporting sustainable and recycled materials, thus limiting their adoption in construction. While other states have incorporated instruments like tax reduction, stamp duty reduction, and additional FAR for certified green buildings, Odisha still lacks such incentives for developers, thus limiting their interest in going green. The BDA Planning and Standards Act has a provision for refunding the fee proportionate to 0.10 premium FAR in the case of platinum or gold-certified IT and ITES green buildings. Yet, there are no such incentives for the housing sector.

Builders are also not receptive to the idea of incorporating sustainable building materials and practices due to the perception that such practices increase construction costs, discouraging the uptake of such materials. There is a lack of demand for

A Commercial cum residential project featuring B+S+9 structure with commercial space on the ground and first floor, and residential flats from 2nd to 8th floors

'green buildings' as markets are driven purely by financial concerns with respect to the upfront costs of purchasing the housing units. Buyers are unaware of the benefits of green buildings in terms of improved living conditions, enhanced thermal comfort, or significant cost savings due to reduced energy demand over the life of the building.

These issues require concerted efforts to ensure that alternative materials and technologies that are made available in the market can be effectively procured and utilised in construction projects. Significant thrust will be required for market stimulation in the initial stages in the form of fiscal support and incentives.

Materials and Technology

Owing to the mineral richness of Odisha, several large industries such as thermal power plants, and steel and aluminium plants are operating in the state. These industries produce large quantities of waste that may be productively utilised for manufacturing sustainable building materials. Despite advanced research and development by the industries as well as local academic institutions regarding several alternative materials, their commercial production is hindered by the lack of demonstration cases and performance validation that can provide adequate data for scientific decision-making. The lack of integration in codes and standards further impedes this process.

Large cities such as Bhubaneswar and Cuttack are facing challenges in managing the construction and demolition wastes generated due to extensive redevelopment and demolition of old structures. Bhubaneswar alone is estimated to generate over 200 metric tonnes of C&D waste per day. While appropriate technologies to utilise this waste exist, these have not yet been deployed on the ground due to the lack of viable business models to produce useful products in a profitable manner.

Further, the arena of bio-based building materials and technologies remains largely unexplored despite the availability of appropriate biomass alternatives and agricultural wastes. The Bamboo Mission was established in Odisha to capitalise on the high potential for bamboo products; however, their application for use as building materials remains largely unexplored.

Recommendations

Odisha has previously shown tremendous initiative and success in transitioning from burnt clay bricks to fly ash bricks through a combination of policy and market initiatives and therefore has a precedent to learn from. Similar zeal is now needed to transform the built environment by creating an enabling ecosystem for new, responsible materials and technologies.

The following overarching recommendations shall be used as guiding principles for designing the roadmap with specific actions across the three thrust areas. The cross-cutting recommendations will be foundational priorities and key enablers to ensure the successful implementation of the proposed roadmap.

Policy Frameworks

- **Visions and Targets** – It is essential to establish a shared vision towards achieving decarbonisation goals and establishing circular material economies for the built environment. Such a vision must take into account the various constraints and opportunities at the state level and institute discrete, measurable targets towards achieving the same.

- **Policy Packages and Frameworks** – Individual, siloed policies will not be sufficient to drive industry transitions. The need is to design cross-sectoral policy packages based on key priorities for implementation. Such policy packages must build in adaptive planning capacities and put in place updatable frameworks to respond to the dynamically changing realities of the sector.

- **Regulations, Codes and Standards** - Combinations of carrot and stick mechanisms are needed to regulate the production and consumption of conventional materials. Appropriate regulations can help eliminate environmentally irresponsible materials from markets. Formulation of relevant quality standards and integration of new materials and technologies into state-level building codes and guidelines will be crucial to enable their effective utilisation.

- **Sustainable Public Procurement** is a key lever for transformative action and can help stimulate demand-side shifts and facilitate the influx of alternative materials and technologies into the market. Building environmental performance criteria and minimum energy requirements into public procurement processes, including tender documents and BOQs, can provide a boost to the demand for alternative materials.

- **Adoption of green building certification systems** – Adopting and promoting mandatory or voluntary green building certification systems such as Eco Niwas Samhita, IGBC, GRIHA, EDGE, LEED, etc. is critical to align building design and planning with sustainable design principles. This can also assist in securing finance for such development.

Markets and Finance

- **Fiscal and Non-Fiscal Incentives** will be necessary to nudge the market towards sustainable materials and meet the high upfront costs associated with the transition. Fiscal incentives may include subsidies, tax rebates, preferential lending, etc. In contrast, non-fiscal measures may include expedited approvals, fee reductions, transferable development rights and other mechanisms to attract developers and architects towards alternative building systems.

- **Viable Business Models** – Production and consistent supply of alternative materials will be hinged on profitable business models that are sustained by regular demand. Innovative business models and delivery systems will need to be designed to ensure that available technologies can be mainstreamed into the markets while ensuring financial feasibility and growth of the local economy.

- **Awareness Building and Changing Consumer Preferences** – There is a need to generate awareness among developers and buyers regarding the benefits of 'going green'. Extensive communication is needed to establish the notion of 'buildings as carbon' and of green buildings being profitable in the long term.

Materials and Technology

- R**esearch and Development Ecosystem** – A strengthened ecosystem is required for innovation in material technologies and providing support for their incubation and demonstration. Furthermore, it would be essential to adopt a forward-looking approach to identify and develop materials of the future, especially bio-based materials and low-carbon, circular technologies.

- **Pilot Demonstrations** – Demonstration cases that can help generate environmental performance data and validate the feasibility of solutions are crucial to bring alternative technologies into the mainstream. These can then be used as best practices for further dissemination and building confidence among users.

- **Rating Tools, Labelling, and Data Frameworks** – Access to detailed, high-quality information on the carbon and resource footprint of materials will be vital to measure and track the performance of alternative materials. This must be guided by a life cycle approach to ensure that decarbonisation and circularity benefits are incorporated in a responsible manner. The end of life of buildings will be important to look at using tools such as Material Passports.

Cross-cutting

- **Multi-stakeholder engagement** - Institutional mechanisms must be established to ensure coordination and coherence across sectoral priorities and bring together various stakeholders for collaborative action. The participation of stakeholders across the buildings and construction value chain will be crucial to derive synergistic benefits and effect change.

- **Capacity Building** – Extensive training and awareness building is required for stakeholders across all three thrust areas across the public and private sectors. This includes policymakers, officials from various government line departments, professionals from the architecture, engineering, construction, and design fraternity, and developers and financiers. Sharing best practices from around the world and specific examples from other states will be instrumental in designing innovative yet practicable implementation pathways for market transformation.

- **Innovative financial instruments** will be powerful enablers for large-scale action at both state and city levels and fill gaps in capital availability for green buildings. This will necessitate setting up institutional financial mechanisms to support industries in producing sustainable building materials and enable developers to incorporate these new materials. These may include instruments such as green or municipal bonds, carbon market revenues, funds from multilateral financing institutions, green housing finance, etc.

A stash of fly ash bricks

Way Forward

The baseline assessment carried out in Odisha provides a comprehensive overview of the affordable housing sector and the various gaps and barriers in mainstreaming the use of sustainable building materials in construction practices. At the same time, there are emerging priorities at the state level that present opportunities to align policy mandates with circularity and decarbonisation concerns to support the government in meeting its development targets as well as contribute to the NDCs and SDGs.

The findings from the assessment will be instrumental in crafting the way forward for the state to initiate coordinated action towards establishing its ambitions and developing actionable strategies to achieve the same. In order to support the state in achieving these goals, a host of activities will be necessary to address various stakeholders across the value chain and ensure responsible action taking into account the life cycle impacts of the proposed interventions. The recommendations laid out above will guide these next steps by establishing priority action areas and implementation mechanisms for the same. The immediate actions to further the ambitions of the initiative are described below.

- **Roadmap Development:** Based on the analysis of the current state of Odisha and the state of its building and construction sector, including guiding policy frameworks, market trends and material flow, a roadmap will be developed based on the GlobalABC Framework through a series of consultations. This will involve exercises for goal setting for the state to establish a clear, shared vision and ambition, and measurable targets based on scientific evidence and projected scenarios for potential pathways. This will help to identify priority action areas for which detailed actions, timelines, and targets can then be established. Further to this, an implementation plan would be designed along with a robust monitoring and evaluation framework to track progress. Institutional coordination and multi-stakeholder engagement will be key features in this process.

- **Institutional Coordination and Technical Support:** With the support of the nodal agency, three working groups will be instituted under the project in Odisha for the development of the roadmap. The working groups will work on three priority areas around which the roadmap shall be structured - Policy Frameworks, Materials and Technology, and Market and Finance. The working groups supported by the project team and headed by a subject matter expert will respectively work to inform policies, standards and regulations, circular business models, develop institutional and financial frameworks and processes, emission reduction strategies, material selection framework and indicators, green procurement frameworks, and research and development of new sustainable materials to mainstream resource efficiency and environmental performance in the building and construction sector.

- **Demonstration of Solutions:** Potential pilot projects in the state of Odisha will be identified with the assistance of the Nodal Agency and key stakeholders, learning from the insights gained through working group discussions. The pilot project will be finalised and put into action through on-ground consultation and community involvement. The pilot projects will inform new policy frameworks, business models, standards and regulations, incentive models, and procurement strategies.

- **Capacity Building:** In order to identify capacities and skills that need to be improved or developed, the project will carry out a capacity needs assessment for stakeholders in the building and construction sector, including policymakers, line departments, AEC professionals, and developers in Orissa. Based in its findings, extensive capacity-building activities will be conducted for various target groups.

- **Knowledge Dissemination:** The learnings from the project will be disseminated through various regional, national, and international events. Knowledge sharing will be a key component within the initiative to enlarge the network of stakeholders engaged in the process and stimulate bottom-up action towards achieving the ambitious targets.

These key steps will be instrumental in initiating a process for transforming the built environment by mainstreaming alternative, sustainable building materials. The long-term mechanisms established through this process will further help to create an enabling ecosystem to drive this change. However, the continued engagement of key stakeholders and ownership of the process by the state will be crucial in furthering the process and ensuring that the desired results can be achieved.

Embracing sustainable materials in construction in Odisha holds the key to a dual transformation - reducing emissions and boosting economic prosperity. The state can significantly curtail its carbon footprint by adopting eco-friendly building materials and construction practices, contributing to global climate goals while enhancing air quality and local ecosystems. Moreover, the shift to sustainable materials can stimulate economic growth by fostering innovation, creating new job opportunities, and attracting investments in the burgeoning green construction sector. The synergy between emission reduction and economic benefits exemplifies a visionary path toward Odisha's greener, more resilient, and economically vibrant future. These actions will help the state of Odisha establish benchmarks for the holistic, sustainable development of affordable housing and adequately meet the needs of its people and the planet.

Large-scale fly ash brick production facility in Bhubaneswar

Use of paver blocks for pathways within the affordable housing complex

A construction worker filling slab uniformly with concrete

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11. Appendices

Table 9
Identified indicators and parameters for energy efficiency measures in standards, guidelines and regulations for buildings in India.

Indicator	Parameter	ECBC	NBC	SP:41	LEED Homes	SVAGRIHA	HECB	Research work
Building envelope	Fenestration properties	✓	X	✓	✓	✓	✓	✓
	Wall–Window Ratio (WWR)	✓	✓	✓	✓	✓	✓	X
	Wall materials properties	✓	X	✓	✓	✓	✓	✓
	Roof materials properties	✓	X	✓	✓	✓	✓	✓
	Air leakage/envelope sealing	✓	X	X	X	X	X	X
	Natural ventilation	✓	✓	✓	✓	✓	✓	X
	Orientation	✓	✓	✓	✓	✓	✓	✓
	Building configuration/alternative design evaluation	X	✓	✓	X	✓	✓	✓
	Height of building	X	✓	✓	X	X	X	✓
	Day lit area	X	✓	✓	✓	✓	✓	X
	Shape	X	X	✓	X	X	✓	X
Site conditions	Topography	X	X	X	X	✓	✓	X
	Distance between buildings	X	✓	X	X	X	✓	X
	Treatment of open spaces/heat island effect-non-roof	X	X	X	✓	✓	✓	X
	Vegetation	X	X	X	X	✓	✓	X
Water and waste water	Rain water harvesting	X	✓	X	✓	✓	X	X
	Water efficient plumbing fixtures	X	X	X	✓	✓	X	X
	Water conserving landscape	X	X	X	✓	✓	X	X
	Waste water treatment and reuse	X	X	X	✓	X	X	X
Building materials	Reuse of salvaged materials	X	X	X	✓	✓	X	X
	Local materials	X	X	X	✓	X	X	X
	Rapidly renewable building materials and certified wood	X	X	X	✓	X	X	X
	Embodied energy	X	X	X	X	✓	✓	✓
	Paints	X	X	X	✓	✓	✓	X
	Cost effectiveness of materials	X	X	X	X	X	✓	X
Energy use applications	Artificial light consumption	✓	X	X	✓	✓	✓	✓
	HVAC-efficiency	✓	X	X	✓	X	X	✓
	Use of electric power	✓	X	X	X	X	X	X
	Solar water heaters	✓	X	X	✓	✓	✓	✓
	Renewable energy generation	✓	X	X	✓	✓	✓	✓
	Solar passive additional elements	X	✓	X	X	✓	✓	X
	Space heating system	X	X	X	✓	X	✓	✓
	Appliances	X	X	X	✓	✓	✓	X
	Efficient power distribution system	✓	✓	X	✓	X	X	X
	Occupancy/green lifestyle/Innovations	X	X	X	✓	✓	X	X
Energy efficiency analysis	Operation energy use and statistics	✓	X	X	✓	✓	X	✓
	Demolition energy	X	X	X	X	X	X	✓
	Life span of building	X	X	X	X	X	X	✓
	Climatic conditions–weather characteristics	✓	✓	✓	✓	✓	✓	✓
	Behaviour of inhabitants	X	X	X	X	X	X	✓

X – Not listed; ✓ – listed

Source: https://www.econiwas.com/pdf/publication/Review%20of%20energy%20efficieny%20intiatives%20and%20regulations%20for%20residential%20buildings%20in%20India.pdf

Table: Distribution of monthly income in Bhubaneswar

Source: Perspective Plan Vision 2030 for BCUC, 2007 [7]

Income groups	Income Range	Existing Distribution pattern-2006 (in%)	Estimated Distribution pattern-2030 (in%)
HIG	above 12500	17.11	20
MIG	5000-12500	45.38	45
LIG	2500-4999	23.01	20
EWS	below 2500	14.5	15

Ready Mix Concrete plant at Bhubaneshwar

About Development Alternatives

Development Alternatives (DA) is a premier social enterprise with a global presence in the fields of green economic development, social empowerment, and environmental management. It is credited with numerous innovations in clean technology and delivery systems that help create sustainable livelihoods in the developing world. DA focuses on empowering communities through strengthening people's institutions and facilitating their access to basic needs; enabling economic opportunities through skill development for green jobs and enterprise creation; and promoting low carbon pathways for development through natural resource management models and clean technology solutions. DA works in addressing three global challenges namely-

Resource Efficiency and Circular Economy-Accelerating the transition to inclusive and circular modes of production and consumption by reducing carbon and material footprints across the lifecycle of economic activity while promoting local value and wealth creation.

Climate Resilience and Ecosystem Restoration-Regenerating lost biodiversity and degraded ecosystems and building resilience to climate change and extreme events in a manner that also generates prosperity.

Livelihood Security and Inclusive Entrepreneurship-Innovative business models and institutional ecosystems to empower local entrepreneurs for creating businesses that generate jobs and deliver basic needs.

Our solutions in addressing these issues are focused in nine sectors- namely Waste Management, Human settlements, Decent work, Climate Response, Sustainable Enterprise, Empowering Communities, Water Solutions, Sustainable Agriculture, and Green Energy.

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