ARTHA GLOBAL
Centre for
Emerging Cities

Localising Green Transitions in India

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About Us

Artha Global is a research, consulting and network facilitating organisation that assists governments in the developing world to design, implement and institutionalise policy frameworks that promote freedom, prosperity, and stability for citizens in the 21st century. We provide actionable research and support policy implementation and institutionalisation. We also create convening platforms to conceptualise new development agendas and build cross-sectoral coalitions across government, business, academia, philanthropy and civil society. Our work focuses on the structural transitions that developing countries must undergo to achieve sustainable and inclusive development. These economic, spatial, social and technological transitions can be summarised as the move from rural to urban, informal to formal, farm to factory, analog to digital and low to high productivity. Additionally, they take place against the backdrop of new imperatives like climate change, gender equity, data privacy and shocks like pandemics. We help governments build the requisite capacity to manage these transitions (and the inevitable dislocations they cause), in order to secure long-term prosperity and social stability for their citizens. All our research, papers, databases, and recommendations are in the public domain and freely accessible through www.artha.global.

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Foreword

When we set out to write this paper, we were guided by the question: what is the role of cities in reducing India's greenhouse gas emissions? We believed that the answer was bound to India's urban form: its streetscapes, buildings and sprawling extents, managed by local governments unprepared for the urbanisation that they service. Urban form does not sit neatly under any one of the sectors traditionally associated with climate change, but transport came close and became the entry point for us. Sprawling cities, connected poorly by public infrastructure with roads too thin to support the bustling traffic, are promoting car use and congestion, and with that greenhouse gas emissions. Projections suggest the situation will get worse.

While transport was our entry point, we wanted to consider the full scope of the city's contribution to emissions, complementing the traditional sectoral approach typically taken by analysts of climate change. The undertaking proved worthwhile, revealing a web of intersections between India's towns and cities and decarbonisation, many of which did not make it into the paper due to the indeterminate ways they can overlap. It also revealed that urban form was only one part of the equation, and that the weak capacity of local governments in general undermined not only their ability to plan for a sustainable built environment, but also their ability to monitor outcomes, enforce regulation, engage with local stakeholders and fund and finance projects in their locales. This is likely to stand in the way of progress on decarbonisation. Tackling climate change is a 'wicked issue', and it will require all levels of government working effectively to bring down emissions, particularly when the target, as laid out at COP 26, is net zero. India's continued urbanisation - and its ability to manage that - will be a key determinant of success or failure.

This paper is intended to start new conversations with stakeholders. Urban management and governance and climate change form a topic that needs more attention, particularly in lower to middle income countries. The rising narrative around cities is rightly the difference they can make in contributing to climate change, but the question of 'how' differs from the current focus on places like London to somewhere like Delhi. This paper has also tended to focus on the most direct links, rather than a whole host of secondary relationships that we came across in our research. Quantifying the impact of governance and relating that to differing programmes and targets in play is another task ahead. This paper marks the beginning of a much longer engagement for Artha Global, wherein we chart out the precise role and responsibilities of cities in achieving the net zero targets in India as well as in countries that are its economic peers.

Definitions

Urban areas

A place having a minimum population of 5,000, density of 400 persons per square kilometre (1,000/sq mi) or higher, and 75% plus of the male working population employed in non-agricultural activities. Places administered by a municipal corporation, cantonment board or notified town area committee are automatically considered urban areas (Government of India, n.d.).

Urbanisation

A complex and multifaceted process involving population migration from rural to urban areas, rural and urban land conversions, spatial reconfiguration of settlements, and changing governance and management. **Urban sprawl** is a consequence of low-density development that is dispersed and uses a lot of land, spiralling outside the urban centres (Heimlich & Anderson, 2001).

Municipality

An institution of self-governance constituted under Article 243Q of the Constitution. Municipal Corporations are bodies for a large urban area, a Municipal Council for smaller urban areas and Nagar Panchayat for an area in transition from a rural to urban area, collectively referred to as **Urban Local Bodies** in the report. Their powers and responsibilities are described in Article 243R to 243Z. **Local Government** refers to the municipality and Panchayats as instituted by the 73rd and 74th Amendments to the Constitution of India (Constitution of India). In this report, local government refers to all urban local bodies.

Urban Development Authority

A planning body created by a State government and given the responsibility of making a master plan, managing land and carrying on building projects (IDFC Institute, 2018).

District Planning Committee

A body responsible for consolidating the plans prepared by Panchayats and the Municipalities in the district and to prepare a draft development plan for the district as a whole (Article 243ZD, Constitution of India).

Devolution

Devolution is the statutory delegation of powers from the central government of a sovereign state to govern at a subnational level, such as a regional or local level (Hauss, n.d.).

Decentralised

Administrative decentralisation seeks to redistribute authority, responsibility, and financial resources for providing public services among different levels of government. It is the transfer of responsibility for the planning, financing, and management of certain public functions from the central government and its agencies to field units of government agencies, subordinate units or levels of government, semi-autonomous public authorities or corporations, or area-wide, regional or functional authorities (World Bank, n.d.).

Centralised

A centralised government is one in which powers and responsibilities are concentrated at the central government

level, rather than the subnational level where autonomy is low. Like decentralisation, it is a multi-dimensional concept with political, administrative and fiscal dimensions (OECD, 2019).

Union government

The institutions set up to represent all states in accordance with Article 1 of the Indian Constitution and creating legislations on subject matters in accordance with Article 246 and those falling under the seventh schedule.

State government

The legislature for every state mentioned in the First schedule as per Article 1 of the Constitution. This legislature is composed of the Governor, nominated by the President, and two Houses, Legislative Assembly and Legislative Council. Members are elected as representatives of state constituencies for a duration of five years. They choose a Speaker and a Deputy Speaker from among them (Constitution of India).

SMART technology

Technologies and devices, such as smart metres, that are able to gather data on situations and to communicate the results of these situations via the internet to other devices and users, who can then change their behaviour to best fit their needs (OECD, 2009).

SMART city

A 'smart' city is one that uses new technologies and data to solve the city's economic, social and environmental challenges (Centre for Cities, 2014).

Green Growth

Green Growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our humans' quality of living also relies (OECD, n.d.). Sustainable Development is a related term, referring to development that meets the needs of the present without compromising the ability of future generations to meet their own needs (OECD, 2003).

Climate mitigation

Climate Change mitigation refers to efforts to reduce or prevent the emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behaviour (UNEP).

Climate adaptation

Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change (UNFCCC).

Net zero emissions

Achieving an overall balance between greenhouse gas emissions produced and greenhouse gas emissions taken out of the atmosphere. In this report, carbon neutrality is used as a synonym (WRI, 2019).

Greenhouse gas emissions

Gases and their constituents of the atmosphere that absorb and emit radiation. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth's atmosphere (IPCC, n.d.). In this report, carbon emissions is used as a synonym as CO2 is often used as the measure of greenhouse emissions because they are the most dominant contributor (Ritchie & Roser, 2020).

List of Boxes

1: Executive Summary

At COP-26 in November 2021, the Government of India announced a five-point plan to tackle climate change, including an ambition to reach net zero emissions by 2070. The multi-pronged nature of the plan, including a shift of 50% of India's energy mix to renewables by 2030, acknowledges that reaching 'net zero' presents a wide and diverse set of challenges.

The pathways to achieving such laudable ambition are still to be determined. Diverse sectors of the economy, from heavy industry to transport to energy to agriculture, face tough choices on how each will drastically lower their emissions, and when. Sequencing the steps that need to be taken will require a unified narrative and an integrated approach if economic growth is to be maintained.

Urbanisation must sit at the centre of the government's vision for net zero. By 2050, around half of the total population will live in towns and cities (Times of India, 2022). India's economy will also be urban, with 49 metropolitan clusters projected to account for 77% of incremental GDP growth between 2012 and 2025 (McKinsey, 2014). Plans to decarbonise will have to proceed in lockstep with these trends. Whether it is the energy demand of buildings, transport emissions from packed roads, the fumes of industry on city fringes, or the lack of infrastructure connecting rural townships, all of India's net zero transitions will manifest in and around its urban centres, meaning they will have to expand sustainably if both growth and decarbonisation are to be achieved.

How India is urbanising must change if it is to be compatible with a net zero agenda. In 2016, the World Bank described India's urbanisation as 'messy' and 'hidden', referring to both its unacknowledged scale and unplanned character (Roberts et al., 2015). Since 1991, the country's urban population has grown by 250 million (Shinoda, 1996). Cities and towns can sprawl for miles without adequate infrastructure and services, and have become environmental hazards, prone to flooding, extreme heat and pollution. They also spew emissions, contributing around two-thirds more per person than rural areas do (see annex).

How urbanisation unfolds comes down to how land is governed. Governments must take granular decisions about what function each piece of land can serve, who can develop it and how flows of people, goods and resources affect its value. They must keep records of who owns the land and consider how transactions of land can be made easier. They must manage the relationships with and between those on the land, whether residents, businesses or public agencies. They must consider the value of the land and the costs of maintaining what is

on it. They must consider where public goods, such as hospitals and schools, should be placed. These are the kinds of issues that inform the broad discipline of urban planning and governance.

India's local governments are not equipped to govern land effectively. Staff lack basic skills, such as in finance and human resources (IDFC Institute, 2018). Technical skills, such as in climate sciences and urban planning, are rarer (NITI Aayog, 2021; UN Habitat, 2020). Data on how cities function is poor and plans for future growth have historically been restrictive, partial, and worsened by messy regulation. The proportion of land designated as public space, which includes roads, green areas like parks and other public infrastructure, is as low as 10% in some city districts, compared to the international standard of 30-40% (IDFC Institute, 2018; Byahut et al., 2020). Poor decisions in urban planning have been linked to serious water scarcity and flooding. Continued misgovernance and failure to act in the face of sprawl, pollution and congestion could cost between a projected $330 billion and $1.8 trillion per year by 2050, or 1.2 – 6.3% of GDP (Tewari & Godfrey, n.d.).

Poor local governance is undermining each of the key transitions that India must go through to reach net zero – in energy, transport, industry and agriculture. Whether it is the regulations around the energy efficiency of buildings, infrastructure choices that promote road use, industrial placement on city fringes, or the lack of infrastructure connecting rural townships, local government's ability to monitor change, plan for development, enforce regulation, and work with the public, private and not-for-profit sectors threatens to stand in the way of progress. It is equally arguable that if they are reformed, they could boost India's achievement of national targets and ambitions.

Furthering India's path to decarbonisation in urban areas requires addressing the causes of poor local government capacity at its root. Cities are over-reliant on Union and state governments to implement policy and development programmes. According to the World Bank, India is the 68th most decentralised country in the world, among 182 countries, while China, its only equivalent in size, is ranked 21 (Ivanyna & Shah, 2012). Funding is centralised too, with local governments relying on transfers from the Union or state governments to fill their coffers (Raghunandan et al., 2016). This leaves local governments with scarce resources and little ability to think and work strategically, hampering the delivery of public goods, to manage growth and withstand stresses and shocks (Puri & Shah, 2018). The challenge particularly hits India's secondary and tertiary cities, leaving them even less room to shape urban growth.

India must find a 'green' way to grow its urban areas. In order to do this, the Government of India and state governments must restructure policy implementation so that local governments become the primary delivery units, at the frontline of development and growth. The legislative approach, through the 74th Constitutional Amendment, has created the room for state governments to implement devolution. Results,

however, have been achieved through closer coordination of departments and programmes, as evident in the Union government's 'Aspirational Districts' programme.

A whole-of-government approach is needed to bring about the necessary convergence. Union and state governments will continue to plan for decarbonisation and set the regulatory framework for implementation; however, they need to enable delivery as close as possible to the sites of action, where development and growth manifest. Urbanisation is the context within which each part of the government must play a specific role while reconciling potential conflicts and stresses. India must transform its urban centres to secure its development trajectory in the direction of a just and green transition. In this paper, we present the following scenario, with decentralised interventions at each tier of governance, as a path forward:

1. The Union government establishes a National Green Growth Platform that supports implementation at all tiers of government.

The Platform will integrate development monitoring indicators and greenhouse gas inventories with geo-spatial data, so that the economic and environmental impacts of transitions in energy, transport, industry and agriculture can be located and their interactions with urban areas understood. Geospatial intelligence is essential for coordinating the country's net zero strategy across sectors and scales. The decision by the Government of India to follow an "area-based approach" for the Gati Shakti initiative, meant to speed up the provision of connectivity infrastructure across the country, already anticipates the demand for such a platform approach. A concerted effort will be required to improve data availability and quality at the local level, building on the ideas of the Smart Cities Mission and the Aspirational Districts programme.

2. State governments provide strategy, oversight and resources to local governments.

States must be re-envisioned as custodians of federal and regional development, holding lower tiers of government to account for district and local area plans and providing more support where capacities are poorest while allowing them to lead on development. Efforts such as updating planning norms and building and environmental regulations and improving land records will provide the lower tier with the framework they need to deliver on the ground.

3. Municipalities and districts become first responders and planners, working hand in hand with the private sector and civil society.

With clearer roles for state and union governments and better support and information for decision-making, urban local bodies and districts can prepare green growth and development plans informed by

their local and regional context in all respects: economic activities, land markets, urban form, environmental impacts, and natural resource management. Evidence-based and sustained engagement with citizens, civil society and the private sector will strengthen the local governments ability to plan and deliver low carbon development projects and public services. The third tier of government will need to enhance its own capacities by mobilising local communities and private sector actors to bring about a broader consensus around plans and budgets.

4. Cities improve revenue streams and financial self-reliance, unlocking Union funds with State government support and securing green finance by de-risking and safeguarding investments.

Increased and timely devolution of funds must become the new normal and revenue opportunities like public land monetisation and carbon taxation should be explored. To ensure investors have the information they need at the local level, information must be spatially correlated. Mechanisms like the National Bank for Financing Infrastructure and Development and state level funds must work with municipalities to secure finance. Financial market regulators, Reserve Bank of India and the Securities Exchange Board of India must bridge the green information gap.

2: Understanding urbanisation and climate change

a. India's 'Panchamrit' stirred: the costs of mismanaged urbanisation

At COP 26, the Government of India announced ambitious plans to tackle climate change. In an approach comprising five targets, named a 'panchamrit' after the ayurvedic drink composed of five ingredients, the world's attention centred on one: the intention to reach net zero emissions, to become carbon neutral, by 2070 (Basu, 2021). Along with targets that included generating 500 GW of renewable energy by 2030 and to shifting the country's energy mix to 50% renewables, the approach signalled that India is alive to the enormity of the task it has set.

To reach net zero presents a hydra of challenges, with diverse sectors of the economy, from heavy industry to transport to energy to agriculture, facing tough choices on how each can drastically lower their emissions. Each choice will have consequences. Citizen's livelihoods will change, funding may be reprioritised, new regulation or changed government processes could be required, the political will must be found across a fractious polity and the right actors—public, private sector, or civil society—must be chosen to help implement and shepherd progress.

Although the 'panchamrit' commitment acknowledges the scope of reaching net zero, the intervention strategy is yet to be articulated. Currently, the approach focuses on increasing renewable energy capacity while providing interim targets to reduce emissions generally across the economy (Mukherjee, 2021). The 2022 budget expands the approach by announcing new initiatives to promote a circular economy, forestry, as well as more detail on plans for increasing renewable energy capacity (Government of India, 2022). However, getting to 2070 will require developing concrete plans to bring down emissions for all major emitters in the economy, backed by a united vision of what this new economy will look like. Only then will the investment needed and the movement of players, public, private and non-profit, be catalysed.

How India urbanises must feature at the heart of the Government's vision for net zero. 125 million people are expected to move to urban areas by 2036, accounting for around 75% of population growth

To reach net zero presents a hydra of challenges, with diverse sectors of the economy, from heavy industry to transport to energy to agriculture, facing tough choices on how each can drastically lower their emissions.

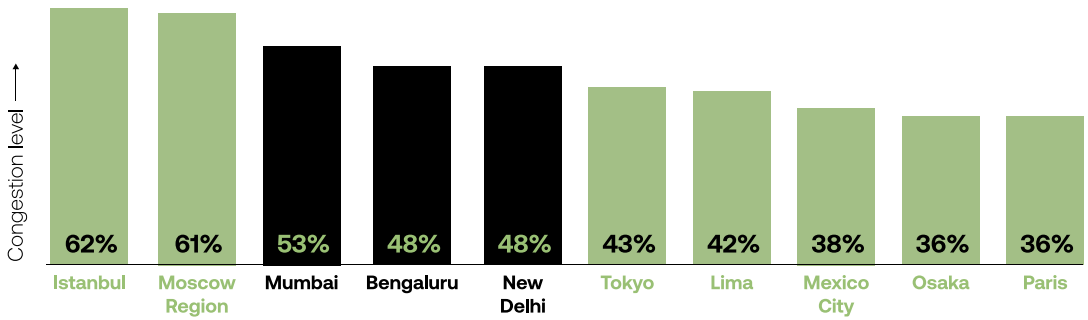
during this period (Government of India, 2020). By 2050, around half of the total population will live in towns and cities (Times of India, 2022). India's economy will also be urban, with 49 metropolitan clusters projected to account for 77% of its incremental GDP growth between 2012 and 2025 (McKinsey, 2014). Plans to decarbonise will have to work in step with these trends.

Whether it is the energy demand of buildings, private transport emissions on packed roads, the fumes from industry on city fringes, or how food gets from farms to forks, many of the transitions India will need to undertake will intersect in and around its urban centres. This means that decisions to decarbonise will also have to balance population growth and economic expansion at the same time. With buildings in India typically standing for between 30 and 80 years, along with their associated streetscapes, urban areas will face long-term choices between higher or lower carbon pathways that need to be balanced with other priorities, local and national (Shukla, 2011). A concerted effort must be made to factor urban areas into the country's plans to decarbonise, to avoid India's future urban footprint drifting in the opposite direction of the country's carbon trajectory.

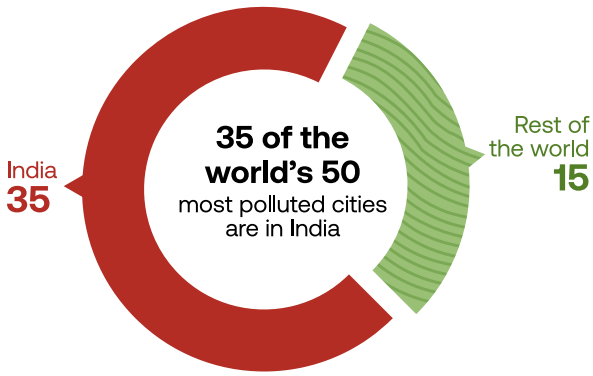
How India is urbanising must therefore change if it is to be compatible with a net zero agenda. In 2016, the World Bank described India's urbanisation as 'messy' and 'hidden', referring to both its unacknowledged scale and unplanned character as 250 million people have spread across its towns and cities since 1991 (Roberts et al., 2015; World Bank, n.d.). Urban areas can sprawl for miles, with 80% of new residents settling on their frontiers, creating congestion because public transport infrastructure has not kept up with development. The placement of buildings, the materials used, their shape and height have created 'heat zones' and trapped pollutants from escaping into the air (Jairaj & Malaviya, 2019). Informal housing is located in flood plains due to a lack of designated space for residential development and the expense of formal construction (Cities Alliance, 2019; Subramanyam, 2016). The result is that the country's towns and cities will be vulnerable to the hazards created by climate change, racking up significant expenses to fix damages, in addition to the pressure of decarbonisation. India's urban areas also contribute around two thirds more emissions per person than rural areas do, unlike countries such as the UK, South Korea, and Malaysia where per person emissions in cities such as London, Kuala Lumpur and Seoul tend to be lower than the national average (see annex). This means for India to meet its ambitions to decarbonise, it must find a way to 'green' the way its urban areas grow, considering both the effects of climate change and mitigation efforts to bring down the cost of intervention.

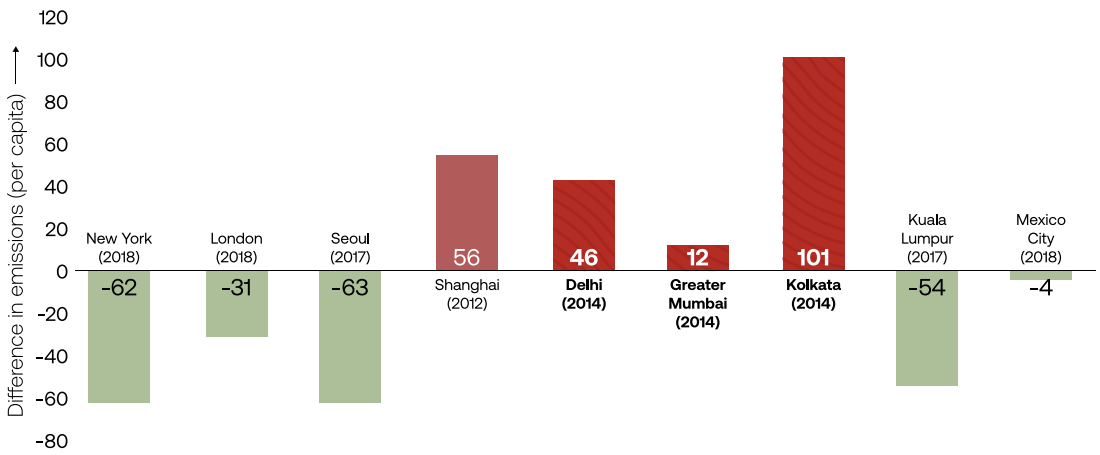
Whether it is the energy demand of buildings, private transport emissions on packed roads, the fumes from industry on city fringes, or how food gets from farms to forks, many of the transitions India will need to undertake will intersect in and around its urban centres.

Box 1: The current state of play in Indian cities



India's cities are some of the most congested in the world



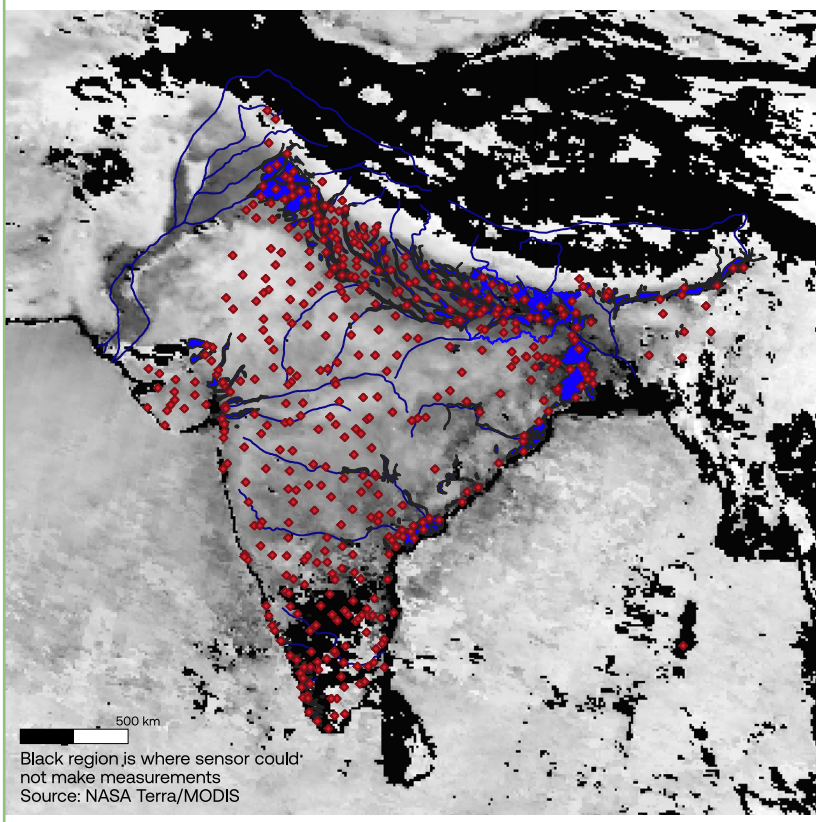


Emissions in Indian cities are higher than the national average - bucking the global trend

(Tripathi, 2021) (OECD, 2021) (Council on Urban Initiatives, 2022) (Ramachandra et al., 2015) (World Bank, n.d.)

Box 2: India's climate and urban geography

Urban areas are embedded into India's economy and as that geography changes, they will change too. Map 1 shows many major urban clusters are located in flood zones, weakening commerce and leaving poor residents at risk. Others are wrapped in a blanket of emissions, making poor air quality a public health concern. Map 2 illustrates aspects of India's energy and transport transitions. The energy grid is currently powered by coal plants that will be replaced by renewable alternatives, such as solar, over time. Given sun intake for solar energy is only optimal in certain locations, plants are unlikely to be as distributed across India as coal plants currently are, meaning no alternative jobs are created unless a transition is planned for. Similarly, the production of steel, required for construction, may have to be connected to new logistics routes using rail and rivers to bring down emissions from road freight. This will change where freight passes through on route to destinations, affecting supply chains and the placement of industrial parks. As these transitions morph and shape, their impact is geographical and towns and cities, as major economic consumers and nodes, will be affected and change too (see annex).



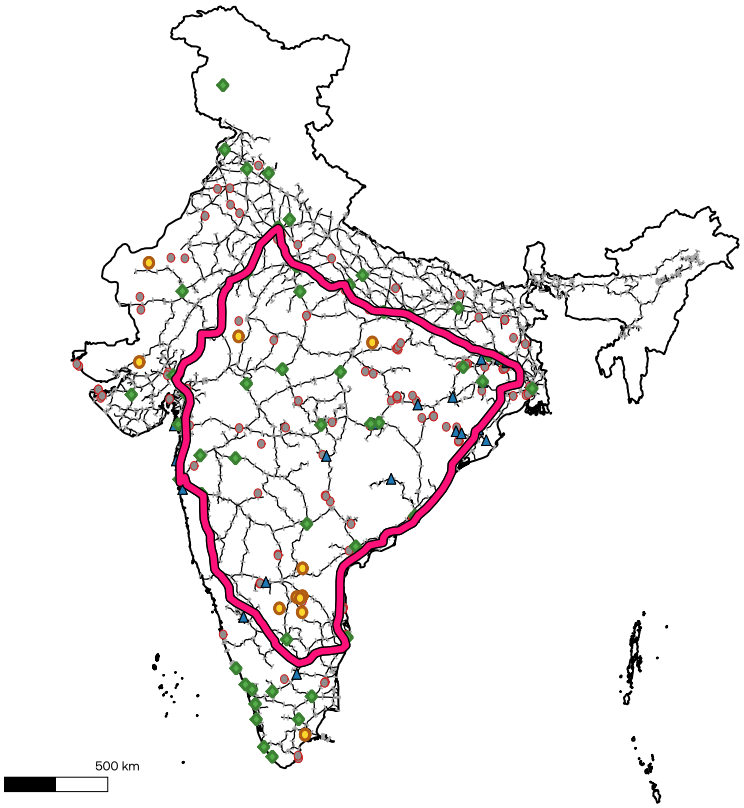
Map 1: Cities in the ring of climate risks

Carbon particles

Low High

Flood Zones

Cities



Map 2: India's energy and production network

Cities with Population > 1 million

Solar parks

Thermal Plants

Major Steel plants

Railway Network

Golden Quadrilateral

How urban areas grow comes down to how land is managed. Governments must take granular decisions about what function each piece of land can accommodate, who is best placed to develop the land and how the flows of people, goods and resources affect the location and usage of land and functions. They must keep records of who owns the land and consider how speedily land can be transacted and developed for remunerative or social uses. They must manage the relationships with and between those on the land, whether residents or businesses. Making the right decisions, governing effectively, can improve the efficiency of the land used, allowing more people to live healthily and work productively, while avoiding the negative consequences of city life, like pollution and congestion.

Most of India's local governments are neither empowered nor equipped to govern land effectively. Staff lack basic skills, such as in finance and human resources, and technical skills related to climate sciences and urban planning are rarely available (IDFC Institute, 2018; NITI Aayog, 2021; UN Habitat, 2020). Data on how urban areas function day to day is poor and plans to govern urban growth have historically been restrictive, partial, and worsened by labyrinthine regulation that slows down development and drives up costs. For example, 45% of India's land is locked up under 'private open space' leaving less room for roads, buildings, public infrastructure and green spaces. The proportion of land designated as public space, which contains roads, green areas and other public infrastructure can reach as low as 10% in some parts of cities, like Mumbai, compared to the international standard of 30-40% (IDFC Institute, 2018; Byahut et al., 2020).

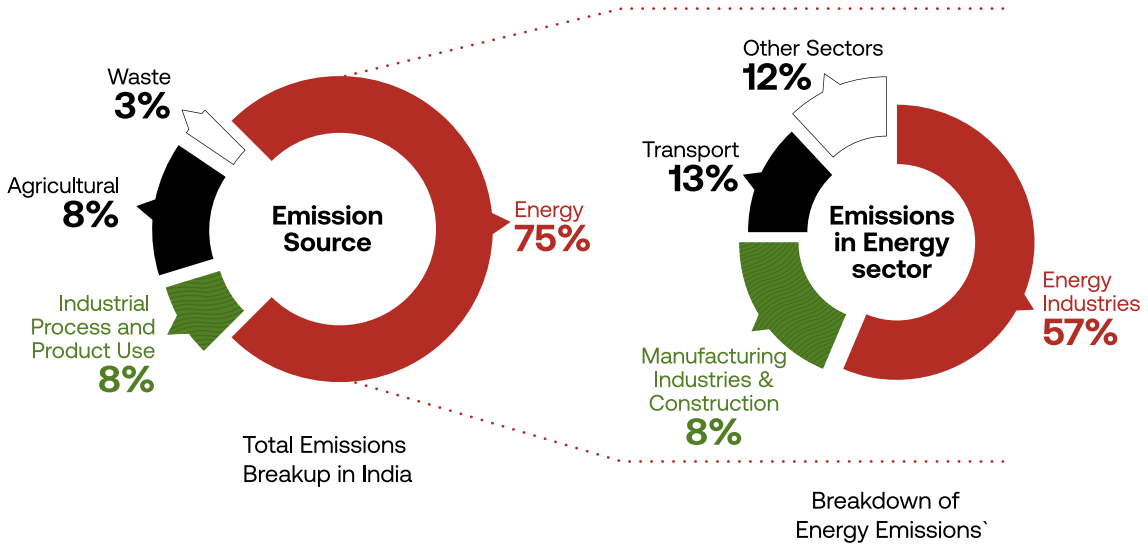
Poor capacity has undermined efforts to adapt to climate change. Only half of India's 53 cities with a population of over one million, which host over 40% of the urban population, have prepared plans to adapt to extreme weather conditions (Singh et al., 2021). Poor urban planning has been linked to serious water scarcity and flooding events (Dhanapal, 2019; Singh & Upmanyu, 2019). The effects of this misgovernance could reach between a projected $330 billion and $1.8 trillion per year by 2050, or 1.2–6.3% of GDP as sprawl, pollution and congestion worsen (Tewari & Godfrey, n.d.).

While the links between the consequences and costs of poor municipal capacity and the impacts of climate change are increasingly apparent, this does not yet account for the added challenge of decarbonisation. Each of the key transitions – in energy, transport, industry and agriculture – that India must go through to reach net zero will also intersect with the country's towns and cities. Without timely intervention, the impacts of climate change will undermine progress on these transitions; but if the necessary reforms are implemented, they could speed up India's transition to net zero.

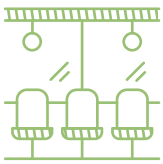
> *Most of India's local governments are neither empowered nor equipped to govern land effectively. This also undermines efforts to tackle climate change.*

b. Urbanisation reconceived: India's net zero transitions in towns and cities

Box 3: India's greenhouse gas emissions and the role of local government



Energy efficiency codes need municipalities to implement



Public transport requires urban planning to improve uptake

Industrial processes can be made more efficient through local outreach

Investing in village clusters can lessen agricultural waste

(Government of India, 2021)

Understanding the effects of poor local government capacity on each of India's net zero transitions is more diffuse, less evidenced and likely to get subsumed by the larger issues described above. Yet, whether it is enforcing regulations to promote the energy efficiency of buildings, infrastructure choices that promote road use, industrial placement on city fringes, or the lack of infrastructure connecting farms, rural townships and cities, the poor capacity of local governments to monitor change, plan for development, enforce regulation, and work with the public, private and not-for-profit sectors in urban areas is an impediment to India's net zero ambitions. This becomes apparent if we examine the specific transitions.

Energy

India's energy transition is the overarching transition that the country must make in order to decarbonise its economy. It is also where India has seen much success, with the country's ambitions growing frequently since 2010 (Garud, 2018). Much of this success centred around the deployment of renewable energy, which now contributes around 25% of the country's installed power capacity, to replace fossil-fuel sources like coal, which still make up the remainder (Government of India, n.d; Roser, 2020).

Weak governance at the local level could stymie efforts to maximise and hasten this transition. Plans to introduce 40 gigawatts of rooftop solar by 2022 are behind schedule, with only six gigawatts having been installed as of November 2021 (Awasthy, 2021). Wind power was also 20 gigawatts behind its 60 gigawatt target for 2022 (Mint, 2021; Sengupta, 2021). For solar, zoning restrictions and building codes in cities have stood in the way of deployment. So has poor consumer understanding about the benefits and incentives of installing solar panels on roofs, which requires extensive public engagement (Goel, 2016). For wind, 93% of delays in projects were due to centrally assigned land allocation, disregarding the local context. Poor planning has been raised as another issue (Sengupta, 2021).

Energy efficiency is the other side of the energy transition, where demand-side measures have significant impact. With energy demand for India's buildings, caused by the need for lighting, heating and cooling, likely to increase by 800% from 2012 to 2047, according to the NITI Aayog, how urban areas are expanded and retrofitted will be key to managing demand (Malaviya & Jairaj, 2017). Currently, the potential for demand-side management remains largely untapped, according to the Bureau of Energy Efficiency (Government of India, n.d.). Regulations are optional and have been left to urban areas to implement, with only 11 states having embedded by-laws across their jurisdictions (Verma, 2020; Chandiwala & Malaviya, 2017). Where local government has

With energy demand for India's buildings likely to increase by 800% from 2012 to 2047, how urban areas are expanded and retrofitted will be key to managing demand.

been left to lead, implementation has been slow (Yu et al., 2017). The Union Government's National Cooling Action Plan, dealing with refrigerant and air-conditioning demand, is likely to run into the same issues as implementation will again rely on local outreach and local level planning (Government of India, 2019; Rajendran & Unni, 2021).

Smart metres are expected to rationalise energy demand, allowing citizens and businesses to monitor their energy use and distribution companies to better understand energy flows (Banerji, 2021). Deployment will again require local outreach. In the UK, convincing homeowners to install smart metres involved local government, consumer groups, local housing officers as well as distribution companies (UK Government, 2013). District-scale energy, heating and cooling systems are another route to efficiency, allowing clusters of buildings to share hot or cold ventilation, effectively recycling energy. Such arrangements would require local bodies to plan in collaboration with developers (Pimpalkhare, 2019).

Improving energy transmission would also improve energy efficiency. High fixed costs, ineffective pricing subsidies and delayed payments have meant energy distribution companies have not adequately invested in their grids (Aggarwal & Ganesan, 2020). The result is ageing equipment and consequent breaks in service, thereby preventing the companies from guaranteeing the normative 24/7 (24 hours, 7 days a week) supply. This means more capacity must be available than needed, for example manufacturers have to rely on back-up diesel generators to keep business going, adding to emissions as a result. For renewable energy supply in particular, technology that could stretch capacity further, such as smart metres or batteries, is missing because of the lack of investment (IFC, 2019; Shakti Foundation, 2014; Regy et al., 2021). Micro-grids and standalone transmission systems run by new distribution companies may have a role to play, by separating new networks from historical burden (Regy et al., 2021; Krishan et al., 2021). Ridding companies of their geographical monopoly so they can compete freely has also been proposed, providing new market opportunities to improve their balances (Regy et al., 2021).

Decision-making around the future of distribution companies should involve local input, which points to a wider role for local governments. Weighing the impacts of different choices, considering how each will affect the local economy, how local communities will respond, how the environment could change, is something that local governments should be well-placed to do, and should underpin urban planning. Such capacities can help elsewhere in energy. For example, local governments could feed into national and state policy to better sequence the closure of coal plants across the country and help place associated national reskilling efforts to minimise the effects of plant closure (Singh & Tongia, 2021). Yet current capacity restricts them from filling this role, leading to national and state efforts across energy policy struggling to translate into action on the ground.

Transport

Transport emissions are 87% from road transportation (TERI, 2019). General vehicular demand will increase by three to four times by 2050, leading to

a corresponding increase in emissions if unabated (Kumar, 2021). Policies to promote electric vehicles are one prong of India's strategy to bring down emissions, with programmes such as FAME II and the National E-Mobility Programme providing subsidies and charging infrastructure (OECD, 2021). These policies have helped commercialise the two and three-wheeler segment, but in the case of electric cars, affordability must increase before wide adoption is possible (Kumar & Kanuri, 2020; Parveen Kumar & Chakrabarty, 2020). Ownership of cars is projected to rise from 22 cars per 1,000 people in 2018 to 175 per 1,000 by 2040, bringing to the fore the second prong in India's strategy: improving public transportation (Economic Times, 2016).

City buses offer a cheap and fast source of connectivity and national programmes like the Jawaharlal Nehru National Urban Renewal Mission have boosted fleet numbers in the past (James, 2018). However, the country continues to have inadequate numbers and coverage by public bus systems. Bihar has less than one bus per thousand people, while India's front runner, Karnataka, provides four per thousand people (OECD, 2021). Ongoing metro projects will help with supply, but both road and rail-based solutions will be required to meet the coming demand and lessen the number of private vehicles on the road (Government of India, 2021). Recognising that walking and cycling to work is still fairly common across the country, with a fifth of non-agricultural workers making their way to their place of work on foot, will be an important factor (DtE, 2016). Keeping these choices attractive will be important as sub national campaigns, like in Ranchi, have attempted successfully (Dutt & Khan, 2021).

"Shift" strategies, that bring together public transport, shared mobility, walking and cycling, could result in an estimated 20-37% reduction in carbon emissions by 2050 (TERI, 2019) (OECD, 2015). To optimise the availability of each choice will be a granular task. Local governments will need to understand the preferences and needs of residents, identify areas that are underserved or would benefit the most from frequent connections, and install supplementary infrastructure, like charging stations for electric vehicles or bike lanes or tree cover for cycling, in streets where space is already limited.

Historically, urban areas have struggled to plan for transport. Dedicated corridors for buses - the 'bus rapid transit' or BRT system – could lessen the congestion encountered by buses and thereby improve the reliability and attractiveness of the service. This was tried in Delhi but the poor design of the system and a lack of public outreach around the initiative led to it being abandoned (Misra, 2016). Delhi's metro is another example. In 2021, it was only used by about 6% of residents due to factors such as high

"Shift" strategies, that bring together public transport, shared mobility, walking and cycling, could result in an estimated 20-37% reduction in carbon emissions.

costs and slow to change commuter preferences (Barman, 2021). In Ranchi, local success has depended on national efforts to stimulate action. When left to their own devices, malaise sets in at the local level. Delhi's public bus fleet for example has shrunk by 40% since 2010, despite national policies to increase them (Roy, 2021).

Similar to passenger journeys, freight too is dominated by road use and electric trucks are not yet commercially viable (Vijaykumar et al., n.d.). Union level projects are therefore rightly in place to move freight away from roads. Sagarmala-Waterways will open up India's rivers to logistics, and several freight-only rail corridors are under development, reversing the trend of freight journeys by rail declining to 30% today from 90% in 1950 (Government of India, 2020; IEA, 2019; NITI Aayog, 2021; Government of India, 2021). Both of these programmes rely on land acquisition and development at the state level; and these factors have already led to delays in developing the new rail corridors (Singh, 2021). The reasons for Sagarmala's slowdown remain unclear, with many projects stuck in the implementation phase, but poor coordination in planning, which is done at the central level, has been suggested as a cause by the Parliamentary Standing Committee on Transport, Tourism and Culture (Business Line, 2021). Delivery of such strategic programmes can be improved only through more informed and evidence-based engagement with those places and their local and regional governments. Like in the energy sector, local governments that can work with communities facing land acquisition and respond to issues as they emerge, could help unblock the transition in the logistics sector. However, like in energy, this new role would require a step change in local government performance.

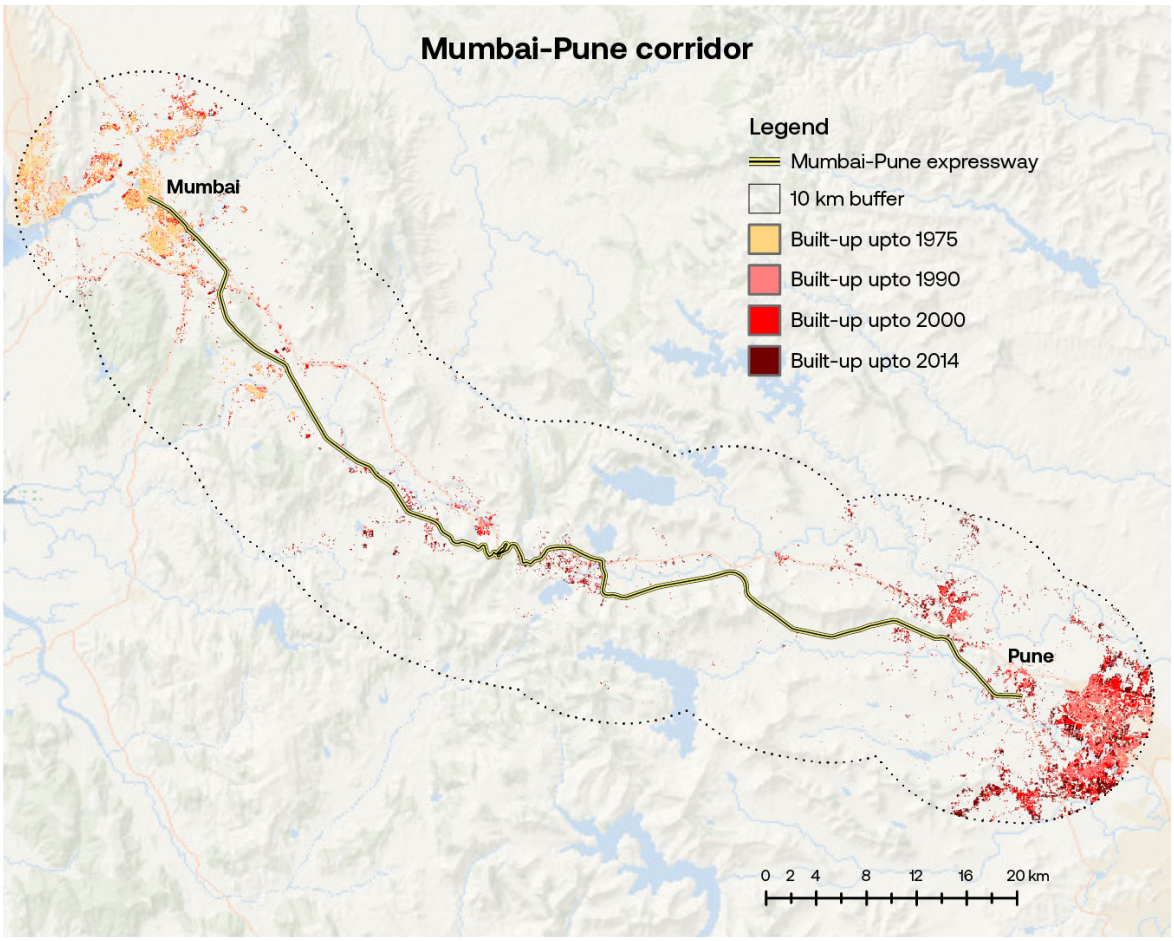
Industry

The cement and iron & steel industries are responsible for 11% of energy emissions (Government of India, 2021). These sectors are likely to grow in the coming decades as demand rises for infrastructure development and construction, particularly to upgrade and expand India's cities and towns (TERI, 2020; Climate Group, 2021). Urban areas and local governments affect the markets for these industries and can play a role in shaping demand.

Improved technology and greater re-use of materials used in industrial processes has brought down emissions and will continue to influence this transition (TERI, 2020; IEA, 2020; Timperley, 2018). Reliable and speedy progress will however be tricky, due to the vast number of micro enterprises in each sector. For example, one leading cement company relies on over 30,000 suppliers. Many of these micro enterprises rely on legacy technologies, are not aware of the economic and environmental benefits of adopting cleaner fuels or more efficient technologies and, in a significant number of cases, cannot afford to upgrade their equipment (Climate Group, 2021; Shaikh & Shankar, 2021).

While there are policies in place to help improve micro enterprise efficiency in these sectors, it is unclear given their sheer number how many can be impacted (TERI, 2019). Micro enterprises in the cement, iron & steel sector are often located on the fringes of cities

Box 4: Mumbai to Pune, sprawling urban areas and transport emissions between regions



Poor quality planning in the hinterlands of Pune and Mumbai for new growth means much of what has developed is situated along the roads that connect the two cities. These are the best places to locate new buildings in the absence of a plan because they have the best and most rapid access to each city, given that major roads into urban centres are few and far between, having not been upgraded or developed. But they do not produce the shortest travel times given their distance from each centre, increasing congestion, pollution and emissions of greenhouse gases. Walking and cycling also become less viable as private vehicles become more attractive to make the long journeys. Poor planning also encourages informal settlements and fragmented development, resulting in urban areas that expand in patches rather than continuously. The long-term effect of this trend is to permanently create inefficient city layouts, furthering the difficulty to intervene and fix the problems of sprawl and to bring down the resulting greenhouse gas emissions (see annex).

and face poor connectivity and mobility, which makes it difficult to provide support to them (Aijaz, 2019). There is evidence that stronger support is needed. A study found that industrial parks could improve recycling if there was stronger communication between different actors on sites and lack of trust was a barrier (Gokulram & Abishek, 2020). Local government is well positioned to facilitate or lead communication at this level and it is the only level of government that can deal with the city's fringes, where communication and access are severely limited. Good practice can be found in Moradabad, where WWF worked with a cluster of micro enterprises to reduce the effluent they were releasing into the Ramganga River. It was WWF's long-term presence in the city and deep ties with local industry that allowed them to engage effectively with these organisations, something that all local governments need to have the capacity to replicate (WWF, 2017). In the longer-term, working in concert with microenterprises to plan and develop industrial parks will offer greater levels of efficiency, reducing industrial emissions further.

Beyond existing techniques and technologies, carbon capture storage and green hydrogen will be required at significant scale to neutralise the sector's emissions. Both technologies are costly and nascent, meaning these industries could be some of the last to decarbonise, especially if demand for their products rises or continues unabated (TERI, 2020; IEA, 2020; Timperley, 2018). Alternatively, demand for iron, steel and cement could be lowered – as the Indian Roads Congress is exploring for road construction (Dash, 2021). Building codes and planning permission mean that local governments can play this role for buildings. Fly ash bricks could bring down the amount of cement, iron and steel needed in a building's structure, for example (Government of India, 2020). Using earth with modern construction techniques has been proposed as a low-cost, environmentally friendly way to build new housing in rural areas (Kulshreshtha et al., 2020). More efficient construction methods could mean that buildings that do rely primarily on cement, iron and steel need less of it, reducing the amount needed to be produced (Malaviya & Jairaj, 2017). Regulatory changes or incentives, like skills enhancement, which can be better delivered at the local level, could help boost the use of these alternatives. Given that the construction sector is fragmented, with only 250 companies with over 500 employees each, understanding what needs to change and what is realistic for the sector to achieve, will require close examination at the local level in order to build a state level or national approach (Deloitte, 2014).

Micro enterprises in the cement, iron & steel sector are often located on the fringes of cities and face poor connectivity and mobility, which makes it difficult to provide top-level support to them.

Agriculture

Livestock (55%), fertiliser use (19%) and rice farming (18%) comprise the main contributors of agricultural emissions and much of the Government of India's efforts to reduce them focus on the farm, such as Pradhan Mantri Krishi Sinchayee Yojana, which will improve water efficiency (MoEFCC, 2021). This is no surprise, as the relationship between agriculture and urbanisation is not immediately clear, but it is equally unrecognised that urban management is not just about cities. Towns are scattered throughout the rural countryside and many are close enough to be clustered together (Ellis & Roberts, 2016). Looking at these strategically, and planning and governing them as regions, can reveal the widened scale at which 'green' infrastructure investments become viable and result in reduced emissions.

The main final market for rural produce is urban areas, where 60% of all food produced is consumed and which represents 80% of the market value of consumption. Districts and municipalities have a role to play in ensuring that the produce reaches end markets with its nutrition intact. With 80% of that food supply having a short shelf life, infrastructure such as cold storage facilities must be in place to stop it spoiling on route (Reardon et al., 2020). Yet, only 3% of food in India is processed before it reaches the end consumer. Inadequate storage leads to high rates of food waste, ranging from 5% to 16% depending on the crop (WRI, 2013; Dash, 2021; Trimach, n.d.).

Reducing food waste has multiple benefits. Not only does it avoid emissions from decomposing food, which releases methane, the main source of emissions from livestock, but it reduces emissions from production on farms because less has to be produced in the first place. China provides an example of what a better supply chain could look like, where less food is wasted because there is storage and processing infrastructure in place, with 20% of the country's GDP output coming from food processing (Marchisio, 2020). Part of why this number is so high is because of strong private and public sector collaboration in rural areas in so-called "Taobao" villages (World Bank, 2019). Together, they have connected farmers to e-commerce, have built industrial parks, and provided training (Wei et al., 2020). Like India, China also relies on micro enterprises to feed its population, meaning what China achieved is not a question of scale (Mitra, 2018; Reardon et al., 2020).

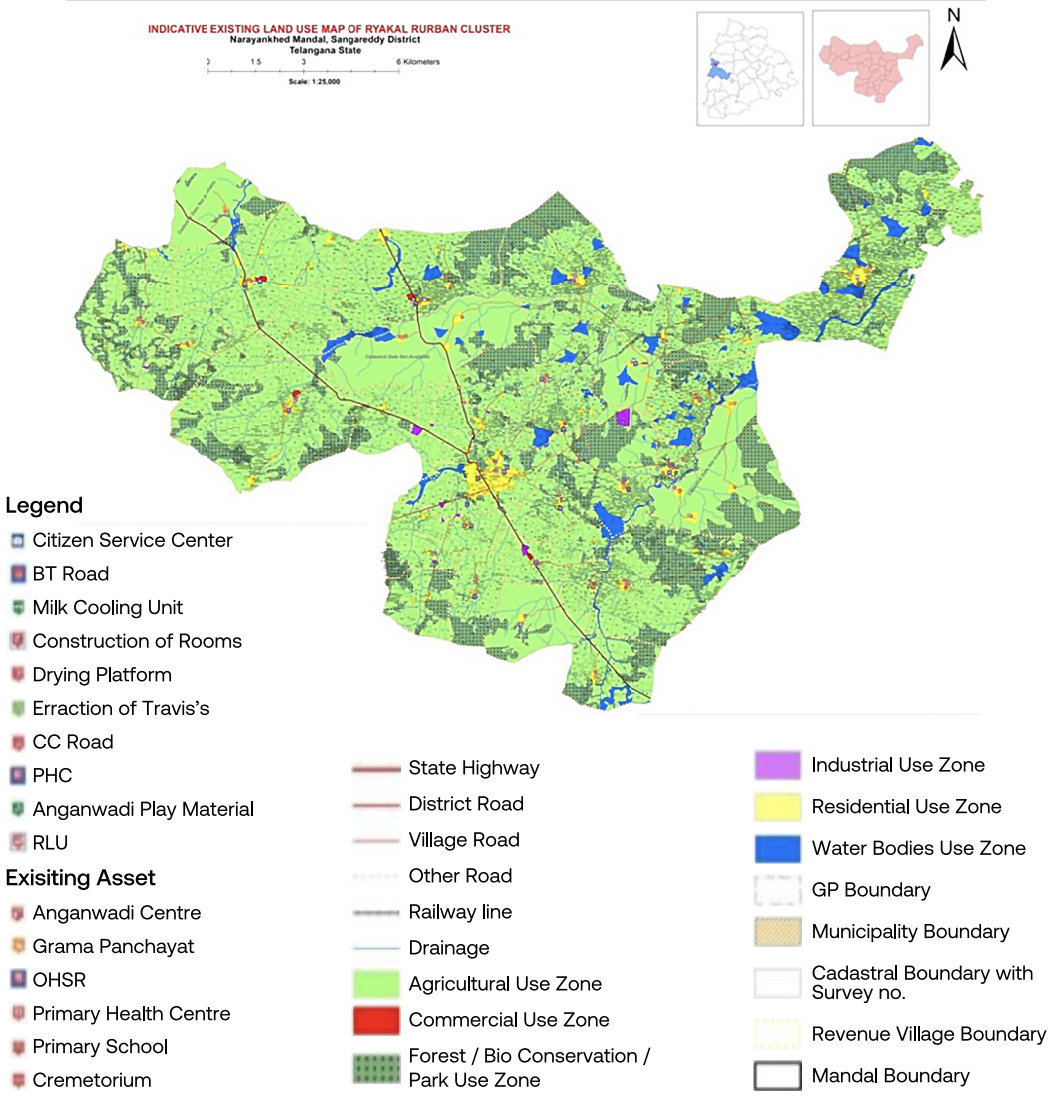
Empowering local government has been tried in rural India. The Government of India's RURBAN Mission clusters gram panchayats, rural settlements with local self-government, to prepare spatial plans for local level infrastructure and economic development, such as improving cold storage. The Mission has struggled to take off due to a lack of state interest in taking advantage of Union funding on offer (Chakrabarti, 2020). Appropriate scales of governance

> *The relationship between agriculture and urbanisation is not immediately clear, but it is equally unrecognised that urban management is not just about cities.*

and coordination are the missing pieces in the Mission. The uppermost tier of 'panchayati raj' is at the zila parishad, an intermediary level between state government and self-governed rural villages, headed by state-level bureaucracies (Government of India, n.d.). RURBAN clusters need autonomy to take over this role, so that they can represent their areas. Instead of relying on the state government to interpret their needs, these clusters could prompt state governments to bid for the funding that the Union government is offering, if not bid for it themselves. Stronger local leadership will provide the right lens to consider local supply chains and connect them and their contributors to wider markets, improving sustainability in the area.

Empowered clusters of settlements could open up other options for lowering emissions on farms. Anaerobic digesters can capture methane and process agricultural waste, turning it into biogas, an alternative to natural gas, and lessening the impact of livestock, replacing stubble burning as well as boosting supply of alternative fuels for harder to decarbonise sectors like aviation (Duff & Lenox, 2019; Abdurrahman et al., 2020; National Infrastructure Commission, 2021). Installing local weather stations will help farmers manage their crops better, lessening wastage that can arise from changing weather (Business Line, 2018).

Box 5: Urban planning in rural areas, rurban and the economic opportunities of clustering



Ryakal is a Rurban cluster in (western) Telangana. With the help of consultation across village level and the district as a whole, and a spatial survey of land use and economic activities, it set out to make its own master plan. The work established that dairy production was an important part of the region's economy and that building cooling infrastructure would better support it. It found other needs, such as improved drainage, and electrification and better road connectivity between each town. It reassessed its land use in this context, considering its conservation zones, agricultural use zones and water bodies amongst residential and commercial uses and then developed its master plan to support the context. The result was a plan that revealed an urban cluster, capable of scaling its economic output that could also continue to preserve parts of its nature. This required reconceiving each town as part of a wider whole, rather than individual places that are not affected by each other (Government of India, n.d.).

3: A roadmap for change

Each transition that India needs to go through to reach net zero – in energy, transport, industry or agriculture – intersects with urban areas and requires capable local government if the transitions are to be successfully delivered. For local governments to rise to the task will require improvements in how they monitor their locales, plan for development, enforce regulation and how they work with local partners to implement change. This will do two things: deal with current challenges, such as poorly implemented building codes for energy efficiency or public transport development at scale, as well as offer new opportunities, like lobbying for infrastructure development and advising the Union and State governments on how to sequence national transitions given local effects.

Revisiting the role and capacity of local government, and with it, the functioning of Union and State governments, who have taken on much of the burden of policy delivery, is imperative. The country is the 68th most decentralised in the world according to the World Bank, with countries like Thailand, with a population equivalent to Tamil Nadu state, more decentralised than India (India Today, 2018). India's only equivalent in size, China, is ranked 21st (World Bank, n.d.).

Funding is overly centralised, creating dependencies that hamper local self-government in its true sense. Municipalities are inordinately reliant on transfers from Union or state governments, and these transfers are typically overprescribed (Raghunandan et al., 2016). Opportunities to raise revenue locally are minimal. One source is property tax, though the amount raised, at 0.48%, is one of the lowest amongst G-20 countries. Peers like South Africa and Brazil stand at 1.39% and 1.25% respectively (IDFC Institute, 2018). This means that local governments must spend their budgets on maintaining and operating existing assets, having little left over for capital investments (Mohanty et al., 2007). The result widens the gap between those with higher economic growth, where more revenue

Revisiting the role and capacity of local government, and with it, the functioning of Union and State governments, who have taken on much of the burden of policy delivery, is imperative.

can be raised locally, and the rest. Initial analysis shows that this skews the patterns of growth and migration of skilled workforce, preventing balanced regional development. This also holds true for climate action – as of 2019, the top performing states were largely those with the best economic performance (Kaur & Singh, 2020). At the city level, it means that India's secondary and tertiary cities remain unfunded and unfinanced, while its megacities like Delhi and Mumbai continue to grow.

Centralisation does not mean that State and Union-led delivery cannot be successful. India has increased its metros in route length from 250 km to 750 km since 2014, urban bodies are saving around $135 million every year as a result of LED street lights and electric bus fleets are being deployed (Khare, 2021; Raghuvanshi, 2021). However, the challenges faced by India's urban programmes persist, since programme delivery requires granular understanding of the function of land, urban block by urban block, the owners of that land, and the nature of flows passing through the land.

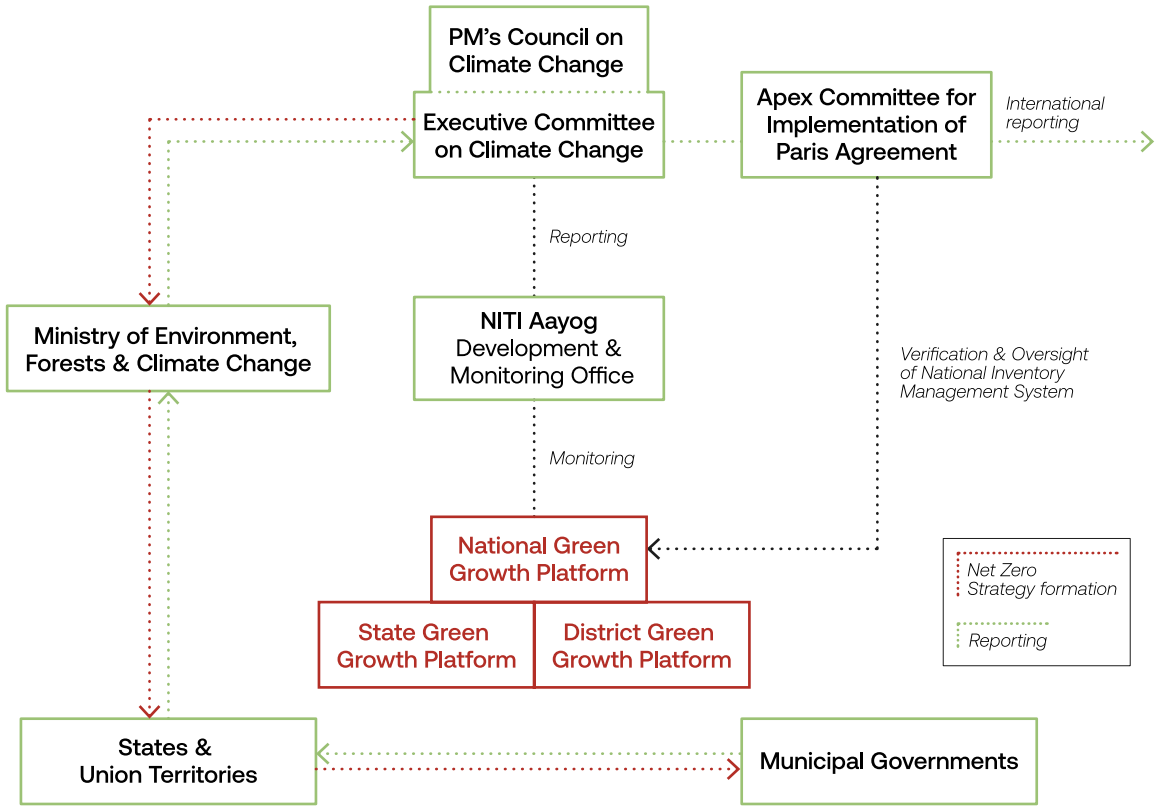
One fix for decentralisation is more power to the state level. The variable quality of State Action Plans on Climate Change, for example, has been placed at the door of a centralised Union government. Low capacity of states to conceptualise large scale projects has also been cited as the reason for underutilization of Union-allocated climate funding (Pillai & Dubash, 2021). Enhancing both the power and capacity of states is needed, but examples like the RURBAN mission show that the question of decentralisation should not stop there. City governments, with differing demographics and diverse economies, geographies and priorities, are closer to the ground and can deal with the nature of detail that state governments cannot, regardless of their power and capacity. In the state of Maharashtra, transport emissions are a significant concern in Nashik; in Nagpur, emissions from housing are a bigger slice of the pie; in Thane, industry comprises a significant bulk of emissions (ICLEI, 2008). To triage decarbonisation trajectories locally requires having a grip on the context and the tools to deliver it.

> *To triage decarbonisation trajectories locally requires having a grip on the context and the tools to deliver it.*

To enable local governments as the delivery units for decarbonisation requires starting from national policy-setting. India must set out a net zero strategy that leverages advances in data science, urban and regional planning, geospatial intelligence and combines these with reforms in governance and finance. The recommendations set out below provide a path forward, which needs to be charted by the Union government but must receive the broader consensus of state and local governments.

1. The Union government should establish a National Green Growth Platform that is implemented at all tiers of government

Box 6: The National Green Growth Platform and its relationship with existing institutions



The pursuit of decarbonisation must start at the Union level, where the transitions the country needs to go through can be seen in granular overview, somewhat akin to high-definition imaging. A long-term national net zero strategy, as required by the Paris Agreement, that outlines a national policy direction and builds on the 2008 National Action Plan on Climate Change, is the first step (Mangotra et al., 2021). The Ministry of Environment, Forest and Climate Change should lead the strategy's formation, working with relevant departments through the Apex Committee for Implementation of the Paris Agreement and a reconstituted Prime Minister's Council on Climate Change. Successful implementation will then require, at minimum, establishing clear metrics for success and failure in each part of the economy that is expected to decarbonise in line with the country's Nationally Determined Contributions. To this end, an improved National Inventory Management System will be needed to support the tracking of these metrics, so that the country's emissions, currently gathered centrally and infrequently, can be better measured and tracked (Rashmi & Gupta, 2020).

To support implementation, we propose that a National Green Growth Platform should be set up to provide a live decision-support system to plan interventions and monitor progress, building on better climate data and the metrics and measurement methods that are being evolved at the Development Monitoring and Evaluation Office in NITI Ayog. NITI Aayog is empowered to undertake comprehensive tracking of policies and schemes of the Government of India and state governments, and is therefore well-placed to lead the establishment of the Platform and its monitoring (DMEO, n.d.). The Platform will ease what has primarily been the Ministry of Environment's burden of collating and monitoring climate data, allowing it instead to focus on developing policy and coordinating with other ministries and wider stakeholders. The Platform will provide a common view for all tiers of government to understand data in its geographical context at different granularities, creating a basis for coordinating planning and delivery.

To set up the National Green Growth Platform, NITI Ayog will need to develop an understanding of how the different transitions, in energy, transportation, industry and agriculture, will play out in the country, how they will affect its geography and how they will intersect with its urban areas. Better emissions data will help, but locating them in the context of the country's geography requires geo-spatial data. Projects do not just exist on paper and their geographical location will inform the risks they will face as a result of local environmental hazards, such as flooding, but also make clearer what impact each transition could have on a local demography, for example by shutting a coal plant or building a trainline near or through a tribal area. NITI Aayog should therefore map the network of urban centres with the spatial footprints of each climate transition to better understand how they interact.

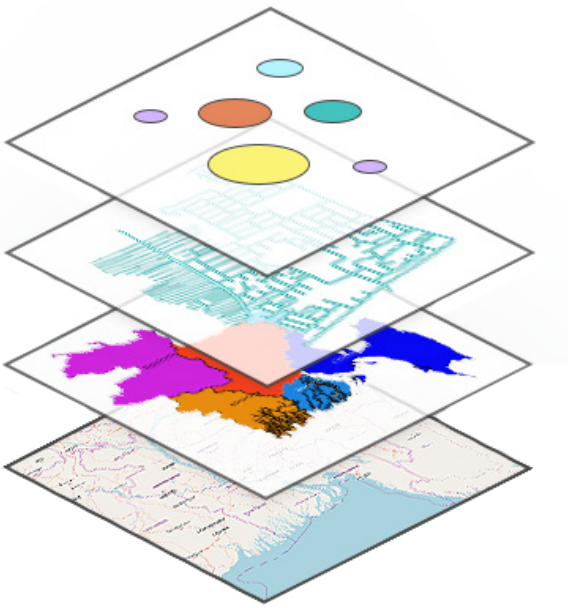
While there is no directly relevant model, and India could well become the first country to have such a platform, a close example is the Geospatial Management Information System used by the Smart Cities Mission to maintain its administrative and transactional information (Esri India, n.d.). The regional thrust of the Green Growth Platform has a cognate in the geospatial platform used by the European Spatial Planning Observation Network, which was established to enhance cohesion within the European Union through coordinated national policies for spatial expansion (ESPON 2020 Cooperation Programme, n.d.). Another example is the GeoDash platform adopted in Bangladesh, which uses open source standards to crowd-source the creation and sharing of maps and geospatial information on an intuitive interface (GeoDASH, n.d.).

To support implementation, we propose that a National Green Growth Platform should be set up to understand how the different transitions, in energy, transportation, industry and agriculture, will play out in the country, affect its geography and intersect with its urban areas.

Box 7: The role of open data in city planning

Bangladesh has set up a Geospatial Data Sharing Platform (GeoDASH) as part of its Disaster Risk Management Framework, with support from the Global Facility for Disaster Reduction & Recovery. The GeoDASH platform is an open source web-based information system set up to empower the government, private enterprise and the public to securely host, manage, update, share, visualise and analyse geospatial data in a collaborative manner.

GeoDASH allows users to create maps, form layers onto existing maps (e.g. storm surge risks, slum area boundaries, major sewerage lines) and view maps in 3D. Planning bodies are then able to access these location intelligence tools to assess disaster risk and climate change data to inform local decision-making. Recently, the Directorate of Primary Education of Bangladesh used the GeoDASH platform to assess the capacity of 35,000 schools to respond to natural disasters by surveying their layouts, water, sanitation, access to roads or shelters (GeoDASH, n.d.).



To make the most of geo-spatial information will require more than tacking additional data sets onto NITI Ayog's monitoring function. The information must be integral to how the Platform is used. To make this happen, geo-spatial data should be used to inform the net zero strategy from the outset, rather than being factored in after plans are readied. Integration of information from the National Infrastructure Pipeline, which will profoundly alter the carbon footprint of India's growth, will need to be integrated on the basis of suitably

complex scientific models. Indicators and plans for each transition would then come from understanding complex linkages. For example, building industrial parks on the fringes of cities to lower industry emissions, or a port to lower freight emissions, may only see the outcomes desired once transport infrastructure is upgraded to support it. The congestion caused by the Chennai Port within the city is a stark lesson in how this scenario can play out (Ramakrishnan and Anand, 2016; Rajamanickam and Ramadurai, 2015). The Platform can help anticipate the contingencies of land allocation and development timelines in detail, thereby helping governments with improved sequencing of development activities.

A data-led strategy is how South Africa designed its "New Deal for Cities and Towns" in 2017. Before the strategy was formulated, a spatial review was undertaken that challenged the government's preconceptions about an urban-rural divide presumed to exist in the country. Instead, it revealed a picture of an urban landscape enmeshed with the rural, much like the case in India (Huyssteen & Botha, 2008). This approach led to urbanisation becoming the central feature of the government's economic development strategy and a new approach to managing it, integrating spatial planning, economic growth, governance and inclusion under one framework (African Centre for Cities, 2016). Funding for small towns and cities has flown from the framework, providing strategic alignment from central government down to municipalities (Parliamentary Monitoring Group, n.d). Similar to South Africa, data gathered for the Platform will inform the net zero strategy with the realities of India's urban fabric.

> *The Platform would need to be hardwired with its equivalents at lower levels of government, in the form of State Platforms and City Platforms for urban local bodies.*

The Platform would need to be hardwired with its equivalents at lower levels of government, in the form of State Platforms and City Platforms for urban local bodies. This kind of integration has been the thrust of the public finance management systems that are gaining in coverage (PFMS, n.d.). These can be set up following NITI Aayog's work to inform the net zero strategy, though that process should be used to introduce states and lower tiers of government to the Platform and what it will mean for them. NITI should then coordinate the subnational development to ensure the Platform coheres at all levels. At the State level, the Platform will allow lower level plans from districts and cities as well as inter-state projects, such as those set out in Gati Shakti, to converge and provide the information to improve coordination between different government actors. At the city level, the platform would inform urban planning and administrative decision-making, specifically to include climate considerations. This would ensure that cities do not inadvertently get locked into long-term carbon intensive projects.

The mere creation of a city-level platform will not be enough to ensure that it will be harnessed for insight. City Platforms should adopt the Data Smart Cities Strategy (National Institute of Urban Affairs & Ministry of Housing and Urban

Affairs, n.d.) and start to integrate data sets not just on climate, but on buildings, public health and other indicators such as the Sustainable Development Goals, currently being monitored by NITI Aayog along with Ministries. There will be voids in the data, but the platform would define the voids better. Covid brought to light a dearth of public sector data, with state governments and academics having to estimate, for example, how many migrated during the period (Pachisia & Gutta, 2021). NITI Aayog's proposed Healthy Cities programme offers a blueprint to develop local, spatialised data. Assessing how to scale the initiative across the country will be an urgent requirement (NITI Aayog, 2021). The extent of ambition for data generally has already been laid out in the Climate Smart Cities Assessment Framework and should be drawn on (ClimateSmart Cities, n.d.).

What data does exist with governments and what additional data is required should also be publicly available information, to facilitate greater partnership between private and public sector in data management. Delivery of net zero will necessarily involve the private sector and civil society and so they must be able to access similar insights at the state level and below to calibrate their roles accordingly (Agrawal et al., 2020). As the Data Smart Cities Strategy identified, changing the culture and processes around public sector information sharing is necessary so that data released does not have to be re-collated by think tanks or civil society for readability, as happened during the development of the Delhi Master Plan 2041 (Pachisia & Parasa, 2021). To facilitate this, the development of the Indian Urban Data Exchange to be used by local governments beyond those involved in the Smart Cities Mission should be facilitated or mandated, allowing all parts of the country to learn from best practice (Dey, 2021).

Delivery of net zero will necessarily involve the private sector and civil society and so they must be able to access similar insights at the state level and below to calibrate their roles accordingly

Getting the National Green Growth Platform and its state and city equivalents up and running will be a significant step. It also opens up a longer-term opportunity to develop 'digital twins' first at the city level. Digital twins use data to assist in decision-making by providing a virtual model of the data's geography, allowing planners and administrators to see what their plans will do in a given environment and how residents will respond based on historical data. It also helps with day-to-day management of urban operations. With real-time data, unlocked through SMART technology, operations can be adapted on the spot (National Infrastructure Commission, 2018). This will take efficiency to the next level, allowing congestion and energy demand for example to be calibrated moment to moment, lessening wastage in the system that cannot be spotted with analogue equipment (Rahiman et al., 2019). In Nashik, Maharashtra, incentives are offered to deploy these technologies in buildings (Sengupta, 2019). Given the opportunity, state or national level policies should be considered.

2. State governments must provide strategy, oversight and resources to local governments

Along with establishing a National Green Growth Platform, roles and responsibilities need to be clarified at each tier of government. Current overlaps create turf conflicts, with state agencies stepping on the toes of municipal authorities. For example, Article 234 W of the Constitution lays down the function of "urban planning including town planning" and "planning for economic and social development" with urban local bodies. However, regional development authorities sometimes step into this municipal role (Pethe, 2013).

In Maharashtra, for example, the state Housing and Area Development Authority and Slum Rehabilitation Authority are both parastatal agencies delivering on construction and slum rehabilitation, which are both municipal functions. This is also true for the construction of roads and bridges, where the Maharashtra State Road Development Corporation is a parastatal agency that undertakes the overlapping function of developing roads within the city of Mumbai (Pethe et al., 2011). Clearer roles need to be determined on the principle of subsidiarity, with each tier of governance playing a role that is appropriate for its level, removing the coordination challenges that naturally arise with multiplicity of authorities, thereby speeding up delivery.

Clearer roles will mean state governments can focus on being the custodians of their economy, but success will require assessing risks and opportunities in a more informed and analytical way. For tackling climate change, this would come in the form of revamped State Action Plans on Climate Change, flowing from the national net zero strategy and informed by data coming out of the State Platform, that can then cascade into district/regional and municipal plans. States must enforce the cascade, particularly for 65% of the almost 8,000 urban settlements in the country that do not have a development plan, and further ensure that climate change is baked into them as they are developed (NITI Aayog, 2021).

To do this, states will have to play a more hands-on role and plan for urban extension, particularly in small and medium towns, where the capacities of the district and ward level governments are the poorest. In the long term, this will require more attention to enabling RURBAN clusters, which would be necessary to rewire the agricultural economy and create agri-processing hubs and the economic emphasis of one-district-one-product, and the logistical emphasis of one-station-one-

Clearer roles will mean state governments can focus on being the custodians of their economy, but success will require assessing risks and opportunities in a more informed and analytical way.

product given in the Union Budget of 2022 (Government of India; Government of India, 2022).

States also need to homogenise planning norms, building and environmental regulations across their districts and hold local governments to account for enforcing them. The intention to modernise building by-laws as announced in the 2022 budget provides an opportunity to do this (Press Trust of India, 2022). Reforming the myriad of regulations will mean the private sector will not have to navigate differing rules, improving access to the market and easing development. It will also allow the state to better coordinate with municipalities and districts on ongoing projects to ascertain why there are delays in development plans, improving the functioning between the State and lower tiers. This is not to say that municipalities and districts should not be involved in what regulatory homogenisation looks like, but it should be the state that sets and holds the framework, allowing local government to focus on understanding how changes could affect local stakeholders, as well as enforcing and monitoring implementation.

States also have a role in improving the utilisation of land through leading the digitisation of land records with municipalities. Land records need to be digitised speedily, an outcome that only some states have achieved so far (Verma, 2022). This will have multiple benefits. The city of Bengaluru managed to increase its property tax revenue by 9% year on year, or roughly $23 million by deploying a GIS-Enabled Property Tax Information System, digitising land titles along the way (Mandyam, 2021). Digitisation will also ease urban development, reducing the possibility of disputes over land, therefore easing land allocation (Jain & Sanan, 2021). This will free up local governments' time to focus on implementing their development plans and allow developers to get on with development.

With the state pulling back from implementation to a framework setting and supporting and enabling role, the conditions will be created for local governments to act as delivery units. The Aspirational District Programme provides an example of what this could look like. The idea is to facilitate stakeholders at the local level alongside state and union governments to think beyond individual programmes, to consider shared goals for the wider economic area, such as development in agriculture and basic infrastructure (NITI Aayog, 2018). Flexible funding to support collaboration underpins local development (UNDP, 2020). Converting such an approach to support net zero, combined with the National Green Growth Platform and clarified responsibilities, will give local governments the space and the vision they need to deliver locally, while keeping higher tiers of government involved.

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While the Aspirational District Programme provides a vision for a more flexible and collaborative governance structure, its potential was not reached partly due to local government capacity (UNDP, 2020). The reality is that states, where most of the capability below the Union level is located, need to lead on capacity building and double down on efforts to improve it at the lower tiers. It may not be possible to hire more staff, but improving basic financial and managerial skills at the lower tiers and helping create recruitment frameworks to attract talent could go a long way (IDFC Institute, 2018).

NITI Aayog's report and the subsequent announcements in the 2022 budget on urban planning capacity, paints a way forward and appropriately places the States' role at the centre. Capacity building should also be factored into State Climate Action Plans and economic development plans to ensure that improving the supply of qualified professionals is seen as a priority (NITI Aayog, 2021; Press Trust of India, 2022). Endeavours to improve capacity should go beyond urban planning and other standard municipal functions to ensure that staff with the technical skills to implement climate related projects are available (UN Habitat, 2020). However, states should not see the task as theirs alone. Making the most of the graduates finishing national training programmes, such as Skill India, and how they can be integrated into municipal cadres means that states can act as a facilitator, rather than a provider, of resources (Dash, 2017; UNESCO - UNEVOC, 2021). Matching cities with urban capacity opportunities from third parties, such as the World Bank's urban gap funding scheme, are an alternative means (Hurst & Wahba, 2020).

3. Local government must become first responder and planners, working hand in hand with the private and civil society

With state and union governments' roles reframed to support the lower tiers, local governments can put together master plans informed by both the spatial and economic elements of their locale, as was recommended by the erstwhile Planning Commission, as well as the net zero strategy (R Arunajayamani, 2012).

In line with clarifying roles and responsibilities across government, plans must be ratified by local bodies themselves, not states, to support this transfer of responsibility and the accompanying expectation to deliver (IDFC Institute, 2018). With this, a selection of other powers, especially the powers listed in the 12th Schedule of the Constitution of India, should be devolved locally. Inter-city and intra-state transport are two different scales and types of management challenges, likewise for energy, water, waste and other environmentally impactful operations. This will also mean that districts and urban local bodies need the appropriate powers devolved to them because in most states, the decisions concerning transportation, say, or water management, are not managed at this tier but at the State level (Kaur et al., 2020).

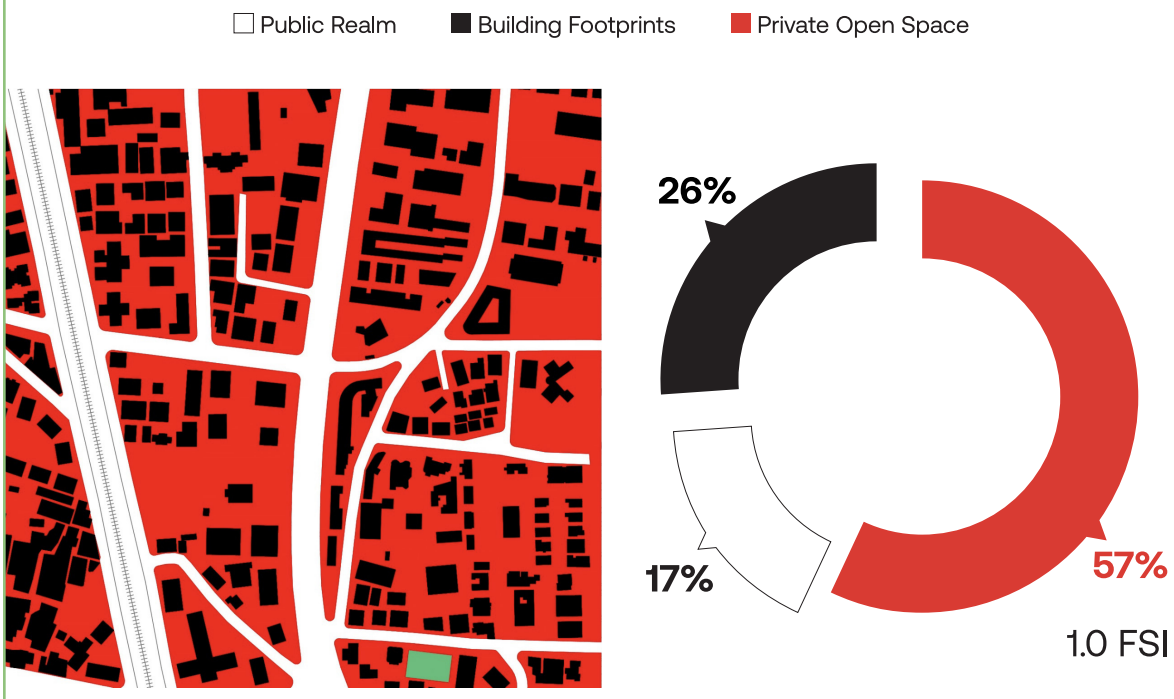
Empowered local governments will have to shoulder greater responsibilities. For example, once a final development or 'master' plan is prepared, the job of the lower tiers is not done; in fact, the land use plans that are synonymous with 'master' plans need to be subdivided into zonal plans and further detailed into local area plans, which flesh out the real world implications of the macro-level policies and regulations. Plans also need to be subjected to continual evaluation and local feedback loops, and not be set in stone. Creating flexible zoning that allows for mix-land-use designations, as was permitted in the 2021 Master Plan of Delhi and taken further in the Draft Master Plan for 2041, will allow development to respond to ground conditions (IDFC Institute, 2018).

> *With the appropriate tools, powers and flexibility, local governments will be in a position to tackle urban planning differently and decarbonise urban development.*

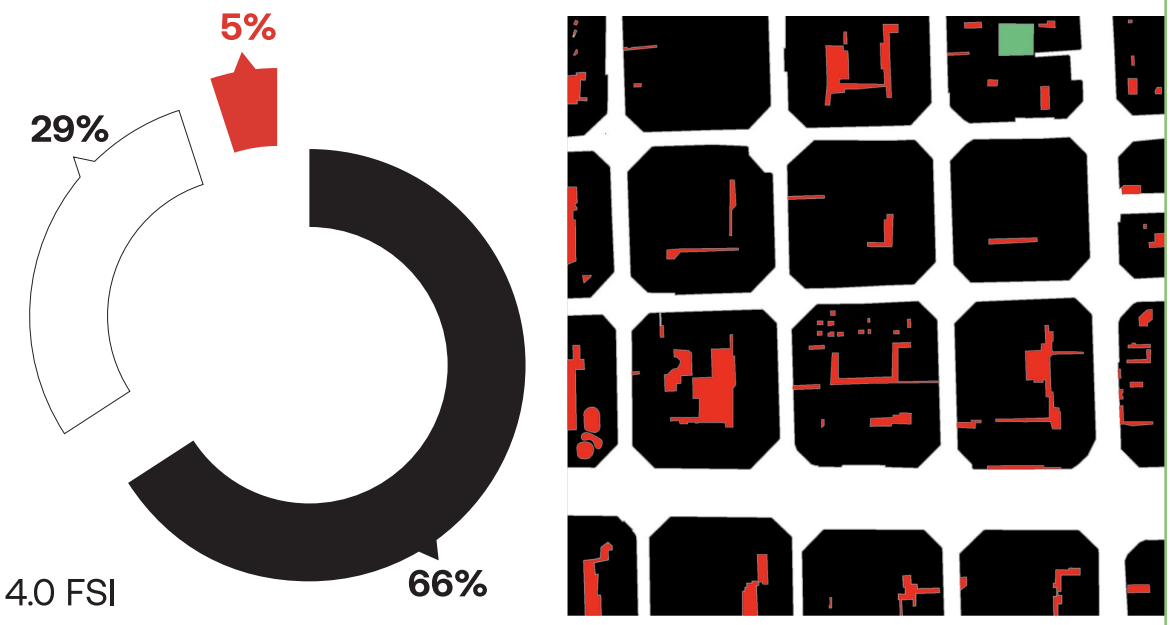
With the appropriate tools, powers and flexibility, local governments will be in a position to tackle urban planning differently and decarbonise urban development. Challenges regarding a lack of public space, and its impact on the local economy and the environment would become clearly visible. They will

> *However, planning and the subsequent implementation of plans should not be seen as solely the job of local government.*

Box 8: Why block density matters



Land utilisation in Ahmedabad



Land utilisation in Barcelona

The floor space index (FSI), which determines the height of a building and how much ground it can cover, is restrictive in India. Most of its cities, including Ahmedabad, have a uniform FSI of about 1.3. In best practice cities, like Barcelona, the number is much higher. Consequently, unlike in cities like Barcelona, buildings are rarely built to the edge of the plot of land under them. The result in India is land wastage. Valuable areas get locked up as private open spaces, leading to lower building footprints and less public open spaces, compared to cities like Barcelona. Getting rid of private open spaces has the potential to make way for robust street networks and more green areas, shortening commuting time and easing congestion, bringing down temperatures and absorbing pollution, amongst other changes that can green their environments and improve residents' quality of life. A smaller building footprint also implies that cities are less dense and have to sprawl, increasing dependence on private transport and thus adding to emissions. (Byahut et al., 2020)

have the room to create an urban plan that is both consistent with national priorities and which triage priorities locally and efficiently.

However, planning and the subsequent implementation of plans should not be seen as solely the job of local government. Capacity constraints in the short-term will mean it needs continued support, not only from higher tiers of government. Harnessing civil society and citizens themselves can augment a local government's ability to both inform planning and assist with implementation. For example, in Ahmedabad, a housing trust, the municipality and a group of technical experts, empowered local communities to conduct heat, water and flood risk assessments of informal housing and assist in fixing arising challenges themselves, like painting roofs to bring down heat or providing advice on where new connections for sewage or water supply pipes were needed (WRI, n.d.).

Unlike civil society engagement, direct citizen engagement is still a relatively untapped opportunity for India and digital technology makes the possibility stronger than ever. Over 15 million citizens reportedly contributed to the preparation of smart city plans for the Smart Cities Challenge held in 2015-16 to select 100 cities for the Union Government's programme, which is being implemented in partnership with State and local governments (Naidu, 2016). Where e-governance has been successful internationally, like in Colombia, local government has played a greater role (Praharaj et al., 2017). This suggests the closer the government

is to the people when undertaking such exercises, the higher the levels of engagement. Given this, whether online or offline, ward level government can play an important role acting as the frontline between citizens and the public sector. This was the case in Mumbai and Kerala during COVID-19, where taking advantage of this level of government improved responses to the pandemic (Mariwala & Shah, 2021). Similarly, the think tank Janaagraha runs an e-governance programme called "I Change My City" in Bengaluru to connect citizens and local government, which has helped improve road conditions and garbage disposal amongst other issues (Janagraha, 2017). Getting to a world where it is local governments that lead public participation initiatives by default will improve the reach and oversight of government programmes on the ground level.

Partnering with the private sector is essential to achieving decarbonisation. Balancing local net zero targets with local economic growth will rely on communication with it. Communication can particularly help micro-enterprises, as discussed above in the context of India's industrial transition, but wider private sector involvement in urban plan formulation will help calibrate its economic effects. Getting frameworks and processes right for public private partnerships, revisiting land acquisition processes, and resolving development disputes in a timely manner are all roles for municipalities and districts too, even if they need support from above to establish frameworks in these areas (World Economic Forum, 2016).

Finally, as local governments mature into their roles, they will have to do their own work to improve their capacity. Municipal cadres can be pushed by state governments, but quality staff retention and procurement of quality technical services will be the job of local government. They can help themselves by working with local organisations, such as academic institutions and policy think tanks, to map staffing needs and other required changes. Organisations like Janaagraha in Bengaluru have filled this role before (IDFC Institute, 2018). Local governments will need to change their internal cultures too. Overcoming the dominant perspective of the middle and frontline bureaucracy as conflicted, unresponsive and caught up in distortionary local and political networks will bring cultural change from the inside (Mehta & Walton, 2014). Performance monitoring cells and encouraging lateral hiring can inject fresh ideas and different perspectives into a municipality (Ministry of Urban Development & World Bank, 2014). Instituting life-long learning pathways could improve retention by showing how careers in local government could grow. While state governments can help inform what a local development framework looks like, it will be up to local governments to implement the sustainable development paradigm.

4. Cities must mobilise greater funding and improve revenue streams; unlocking financing opportunities through state mechanisms and green information.

With a National Green Growth Platform aligning the national view with the local, the Union and State governments providing a framework for local implementation, and the capacity of local governments boosted to create nuanced development plans, the framework will be in place for low carbon urbanisation. Yet, with fewer funding and financing opportunities at the third tier, particularly in secondary and tertiary cities, change is needed to pay for it.

Of total green investment in India in 2017-18, the share funded by the Union government amounted to 18% (Acharya et al., 2020). Of this allocation, local governments received the smallest proportion. If local governments are at the mercy of funding decisions made above them, their ability to implement change on the ground, like for public transport, wider roads and green spaces, will continue to be at risk, undermining development pipelines. Funding allocations made for climate actions also remain unspent. The National Clean Energy Fund is an instance where Union level action was deficient. An allocation of $7.4 billion, to be spent on clean energy and environmental projects, was redirected to compensate state governments for unrelated revenue loss (Shrivastava, 2017).

At the Union level, India is one of the few countries that provides inter-government transfers for climate action down to the state level. This transfer should also be routed to the local government as a first step towards greater funding devolution. The transfer plan is conceived by the Finance Commission. In addition to transferring the funds, the conditionality for receiving the transfer must also be expanded from being just one condition at present – afforestation and the making of carbon sinks – to promoting multiple other actions for climate change mitigation (Chakraborty, 2021).

State governments must also come through on transferring the funds they owe to local governments. Over the years, the share of transfers allocated for carrying out functions of local governance by the Fifteenth Finance Commission has increased by 39% compared with its predecessor (Pathak, 2021). In practice, a substantial part of the sum is at the discretion of State Finance Commissions and does not get to local governments. Commissions can be arbitrary in their release of funds and lack a consistent principle for making these transfers, in a complete contrast with the way the Central Finance Commission transfers money to the states. Several states have even failed to

If local governments are at the mercy of funding decisions above them, the ability to implement change on the ground, like for public transport, wider roads and green spaces, will continue to be at risk, undermining development pipelines.

set up their State Finance Commissions in a time-bound manner (Gupta & Chakraborty, 2019).

To improve devolution while also dealing with the realities of state allocation, Union level criteria should be introduced that provides for both state and third tier spending, while also asking states to monitor local government spending. To make this work, a significant tranche of funds at both tiers could be dependent on regional priorities set out in the State Action Plans for Climate Change, and local governments plans that are developed under them. This will mean that states do not lose out, having both their own set of funds and oversight of funds spent at the lower tier.

Local governments must also raise more revenue. Monetising surplus public land offers one such source. By one estimate, the value of the surplus public land, for just the city of Ahmedabad, could be $5.9 billion (Annez & Gangopadhyay, 2013). The National Monetisation Pipeline, conceived by the Union government, to identify brownfield assets for long term lease or disinvestment and use the financial proceeds from them to reinvest in creating new infrastructure, can offer a model for city governments to replicate. (NITI Aayog, 2021). To set up something at the city level successfully however will require state support. Surveys will have to be carried out to identify surplus public land and auctioning mechanisms will have to be designed to realise maximum value. Capacity can be built in municipalities over time so that they can fulfil this function in future funding drives; however, procurement of services will need to be done immediately to deliver the infrastructure pipeline.

Land value capture offers another potential source of revenue for urban local bodies. It can be raised against infrastructure in the form of a betterment levy, to compensate for appreciation in their land value once the infrastructure is up and running (Ahluwalia & Mohanty, 2015). Carbon taxes in the form of congestion pricing could be pursued too (Ponkshe, 2019). Ultimately, a package of revenue raising tools will need to be pursued to provide the base level funds for municipalities to adequately invest in themselves. However, given capacity constraints and the lower value of revenue streams available to smaller cities compared to cities like Bengaluru, balancing how much funding and support is provided by state governments, versus what levels of revenue are expected to be raised locally will require an adaptable formula that can be adjusted as cities develop.

> *The success of implementing a net zero future is going to depend on significant infrastructure financing.*

Apart from getting more resources to local governments, the implementation of a net zero future is going to depend on significant infrastructure financing. At COP 26, developing countries pointed out the need for such levels of investment, reminding developed nations of their $100 billion a year commitment. The Government of India plans to lay down an investment pipeline to attract funds for sustainable development under its master plan, Gati Shakti, as highlighted in the 2022 budget (Government of India, 2022).To guarantee its success, the government will have to work with municipalities to

generate funds and de-risk investments.

The steps on the way to realising infrastructure development start with geo-tagging each project. This will identify which municipality, in what region, will need to be coordinated with. The spatial information of every project must be integrated across all government platforms, such as the Public Finance Management System and the proposed National Green Growth Platform. Integrating the spatial location of infrastructure projects with the Public Financial Management System can ensure money required for its implementation reaches the right local body through direct transfers, helping reduce project delays arising from central implementation as happened in the rail-freight corridors project discussed above.

The new National Bank for Financing Infrastructure and Development will also need to work with local governments. Its mandate is to "support the development of long term non-recourse infrastructure financing in India including development of the bonds and derivatives markets necessary for infrastructure financing" (The National Bank for Financing Infrastructure and Development Act, 2021). Apart from lending to municipalities, the development bank can help realise its mission by supporting municipalities to become participants in the bond market. Green municipal bonds can potentially tap into the reserves of institutional investors who have deep pockets and who are eager to integrate the Environment, Social and Government commitments into their investments (GIZ, 2017).

This model of a development bank must be replicated by the state governments that already have financial intermediaries, which could be capitalised through the new bank. Other states have to be encouraged to replicate the good practice. Not every municipality will have the capacity to float bonds or the creditworthiness to attract money for a successful issue. Such municipalities should be able to reach out to a source of infrastructure funding where these issues are dealt with already. The Tamil Nadu Urban Infrastructure Financial Services Limited is an example of one such institution. It is a fund managed as a corporation by the state government of Tamil Nadu in collaboration with financial institutions like ICICI Bank, HDFC, and IL&FS (TNUIFSL). Its stated objective is to fund urban infrastructure projects and enable them by providing access to debt finance from capital markets, allowing municipalities who might otherwise be overlooked, to get the funding they need.

Apart from funding local governments and raising infrastructure finance, the involvement of capital markets will have to be tapped to bring down the cost of capital, increasing the number of projects that can be actualised. Between 2000 and 2019, India suffered economic losses worth $80 billion due to climate change disasters (Balakrishnan, 2019). Financial experts agree that the top risk

The potential of capital markets will have to be tapped to bring down the cost of capital.

for business will be the physical risk from climate change over the next 30 years (Stroebel & Wurgler, 2021). A recent ICC Report highlights the risks to coastal areas, where, over its 750 kilometre long coastline and along its deltas, many of India's urban populations are located (IPCC, 2022). With the help of regulations, capital markets can help investors to pool, price and exchange these climate risks, in turn lowering the cost of capital for projects that will mitigate climate change. The Securities and Exchange Board of India (SEBI) and the Reserve Bank of India (RBI) have a role to play here.

SEBI's role is to enable corporate disclosures on their carbon intensity, along with helping businesses to protect themselves against the physical risks of climate change. By increasing the access to carbon information, investors can factor climate related risks into decision-making. The Task Force on Climate-Related Financial Disclosures has set out various disclosure requirements that regulators must help mainstream into capital markets (Singh et al., 2020). This will bridge the information gap for green finance and reduce investment risks and the cost of capital. If other countries introduce climate related reporting standards first, this will have an impact on export oriented Indian organisations if the country does not move fast enough (Task Force for Climate Related Disclosures, 2020). As well as avoiding the penalties of opting out, aligning with global norms will benefit Indian firms by making sure they do not miss out on international green investment. Going forward, developing a green taxonomy will be another necessary condition to bring together global capital and attract international green finance institutions, who have historically shied away from participating in Indian markets (D' souza, 2021). The market regulator has taken a lead in this by notifying guidelines on reporting sustainability of companies and the projects under them, so progress is already likely (SEBI, 2021).

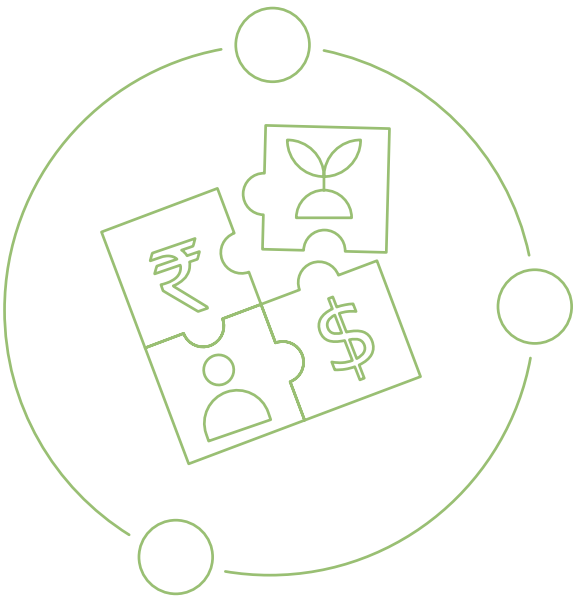
RBI's role will be to help investors become conscious of how their investment decisions can have an impact on climate change. It has acknowledged this need, stating it should work to "incorporate environmental impact into commercial lending decisions while simultaneously balancing the needs of credit expansion, economic growth and social development" (Rao, 2021). Many corporations have begun taking steps towards voluntarily pricing carbon in their business (Hingne & Agarwal, 2021). For the remaining corporations, a push from RBI can help realign profit motives with a net zero agenda.

A final mechanism for pricing carbon is by creating a market for carbon trading. Under that, the supply of emission quotas for participants is controlled by regulators and additional allocations can be traded in exchanges (IEA, 2020). This market based approach has become popular across many developed nations, with the European Union's Emission Trading System becoming a "cornerstone of the EU policy to combat climate change" (EU ETS). While India has a series of schemes that come close to this, it does not have an explicit trading mechanism. City governments can fill this gap by setting up their own emission trading systems. The industrial city of Surat in Gujarat, has set a precedent by creating the world's first Particulate Trading System that is projected to decrease emissions by 30% at the same time as increasing average profitability of the participating firms by

$7000 per annum (Greenstone et al., 2019). Every industry and participant is allocated an emission quota it is allowed to emit and once breached, it has to trade for an additional allocation in the market. This enables a local market mechanism for pricing carbon. The government can change the allocation of emission quotas and the firms will change their behaviours in response, without affecting their profitability. This is a model that can be replicated in other metropolitan regions of India too, and could go beyond particulate matter, providing accurate information on climate-related risks at the local level, improving investor confidence.

Conclusion

With finance unlocked through better signalling and accounting of risk, and local government funded and upgraded to identify, attract and implement investment opportunities appropriate for their contexts, the synergy in different components of the growth engine and the delivery of India's net zero will be ready. There is an added benefit. Leveraging data, urban and regional planning, governance, funding and finance will not only allow India's urban areas to be transformed and the road to carbon neutrality shored up, but a green dividend will be unlocked. Resilient, future-proofed infrastructure, the new default in a green investment framework, will return a $4 benefit for every dollar invested (World Bank, 2019). Investors' interest will blossom, potentially unlocking an investment opportunity of up to $15 trillion to fund India's climate transitions that could lead to around 50 million jobs (World Economic Forum, 2021). Improved funding at the local level, with increased opportunity to raise financing, will speed up development timelines. Better relationships with the private sector and greater drawing on civil society and citizens will ease the government's job, finding cheaper, local solutions to each climate transition, easing resource strain to be spent on other needs of the country. Clearer relationships at each level of government with improved communication through the National Green Growth Platform, will improve the attractiveness of the Indian marketplace, with a mission oriented, responsive and transparent Union government ready to support and lead at all tiers. With a net zero strategy that transforms the governance of the country and how it urbanises, not only will the costs of climate change be avoided, but the promise of a $5 trillion economy will find viability through sustainable and resilient urbanisation.



Technical Annex

Mapping

To better understand urban areas' role and function in transitions India would need to take to become a low-carbon economy, we decided to explore this from a geographical perspective, in order to understand how they interact with them currently and how that would change. While there is significant literature on the role of cities' in decarbonisation in India, we found there was limited work that considers this through geospatial mapping. Previously, Artha Global staff have conducted extensive mapping exercises on urban expansion, mobility, and economic developments to better understand the role of cities in the Indian economy. We drew upon these datasets and overlaid them with information on India's transitions for this exercise. The results and the methods are set out below.

Software used for all maps:
QGIS: QGIS is a free and open-source cross-platform desktop geographic information system application that supports viewing, editing, and analysis of geospatial data (https://qgis.org/en/site/).

ArcGIS: ArcGIS is a family of client software, server software, and online geographic information system services developed and maintained by Esri (https://www.esri.com/en-us/arcgis/about-arcgis/overview).

Geoserver: Geoserver is an open source java-based software, which allows users to edit and share geospatial data while GWC stores all the TMS (Jpeg, Pbf and Png) layers in order to increase loading speed of layers (http://geoserver.org).

Mapbox GL: Mapbox GL is a Java Script web mapping open source library. It makes it easy to put any dynamic maps in web pages. All the data was displayed by using Geoserver TMS layers (https://docs.mapbox.com/mapbox-gl-js/api/).

Box two: India's transitions and their relationships to towns and cities

Map 1: Cities in the ring of climate risks

Our aim here was to understand which regions were most vulnerable to the effects of climate change. We used two layers of base maps - aerosol index and flood zones to establish the context of current environmental conditions. We then added data points to show the locations of major urban clusters in the country and found that cities are concentrated in climate vulnerable areas like the flood zones or regions with poor air quality.

Dataset Sources:

1. Real-time Aerosol Optical Depth, Observations from Moderate Resolution Imaging Spectroradiometer on NASA's Terra satellite (https://earthobservatory.

nasa.gov/global-maps/MODAL2_M_AER_OD)
2. Vulnerability Atlas of India, 2019, Flood Hazard Map, 3rd edition (https://vai.bmtpc.org/flood.html)
3. Population of Urban Agglomerations/ Cities, Census of India, 2011 (https://censusindia.gov.in/2011-prov-results/paper2/data_files/india2/million_plus_uas_cities_2011.pdf)
4. Geolocations of Cities, Indian Cities Database, Simple Maps (https://www.kaggle.com/datasets/parulpandey/indian-cities-database/metadata)

Map 2: India's energy and production network

Our aim here was to get a spatial understanding of the climate transitions in India through the lens of energy generation sources and production networks. We focused on these two stories because of the availability of granular data, as opposed to in other domains such as grid infrastructure. We plotted thermal and solar plants to illustrate regions having a higher potential for generating electricity through renewable sources. Additionally, we plotted the locations of India's million-plus cities and major freight corridor networks to understand the main routes for freight into major urban areas and how they may change to reduce freight's reliance on road networks, required if the sector is to decarbonise. Additionally, we plotted steel plants on our map to understand whether this industry, with strong demand for its product in cities, was also reliant on major road networks and would also have to be connected to new freight routes using rail and rivers. Overlaying rail and road was found to be non-reader friendly when displaying the map, so was removed from the final display, bar the golden quadrilateral. This was included due to steel plants being located close to it, illustrating our findings that there was a relationship between steel plant location and proximity to road networks, suggesting that logistics routes would have to change if freight was to decarbonise. To include the quadrilateral, we used the Indian roadway map (https://tinyurl.com/yuj2k7ph) and manually georeferenced and traced it on QGIS to create the road network.

Dataset Sources:
1. Locations of Power Plants - Global Energy Observatory, World Resources Institute, 2018 (http://resourcewatch.org/ https://earthengine.google.com/)
2. Railway Network - DIVA-GIS (https://www.diva-gis.org/gdata)

Box 4: Sprawling urban areas and transport emissions, Mumbai to Pune

We wanted to understand how and where urban sprawl happens over time. The Mumbai-Pune expressway is one of India's busiest roads and the primary road infrastructure connecting the two metropolitan cities. Therefore, it was important to understand if fragmented development along this transit corridor could be a potential factor in increasing road use. This map was created by UXO-India using the Global Human Settlements Layer (GHSL) data. It shows the footprint of built-up areas in 1975, 1990, 2000, and 2014. It suggests that fragmented development has indeed

led to increased use of current road infrastructure, thereby increasing congestion and greenhouse gas emissions.

Dataset Sources:
1. Built-up: Global Human Settlements Layer - Year up to 2014 (http://ghsl.jrc.ec.europa.eu/)
2. Basemaps courtesy of Mapbox, Carto, Open Street Maps and Cesium, Geoserver 2.11.2 for processing and Mapbox GL (JavaScript) for front-end development.

Other

Urban areas contribute two thirds more green-house gas emissions to India's total than rural areas do

We wanted to understand if urban emissions were higher than rural emissions in India. To understand this we adopted two approaches. Firstly, we put together district-level data from the census and carbon footprint from Lee J. et al. referenced below. We classified the majority of the districts into urban and rural with the help of urban census definitions: i) A minimum population of 5,000; ii) At least 75% of the male main working population engaged in non-agricultural pursuits; and iii) A density of population of at least 400 persons per sq. km. We then calculated overall urban and rural emissions, and found that urban per capita emissions are 64% higher than rural emissions. But census urban definitions are not meant to be applied at the district level. Hence, we used the dataset provided in Daniel Moran et al. which includes urban-rural population and carbon footprint. The second dataset gave us a similar result. For ease of reading, we rounded this to urban emissions per capita being two-thirds higher than rural emissions.

Dataset Sources:
1. District-level Census data - Population Enumeration Data, Census of India, 2011, (https://censusindia.gov.in/2011census/population_enumeration.html)
2. District-level Carbon footprint data - Lee J. et al., 2021, "The scale and drivers of carbon footprints in households, cities and regions across India", Global Environmental Change (https://doi.org/10.1016/j.gloenvcha.2020.102205)
3. Carbon Footprint of urban and rural regions - Daniel Moran et al 2018 Environ. Res. Lett. (https://iopscience.iop.org/article/10.1088/1748-9326/aac72a)

Currency conversions

All monetary sums are in USD. All INR values were converted into USD using the average exchange rate of $ 1 = Rs 73.9 for 2021. Some numbers are not reflective of actual USD - INR exchange rates at the time but given the timescales and the largeness of the values quoted, they are precise enough for the purposes of the paper. All references to original numbers and currencies are included for those interested.

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