

Can low-carbon urban development be pro-poor? The case of Kolkata, India

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ABSTRACT Fast-growing cities in the global South have an important role to play in climate change mitigation. However, city governments typically focus on more pressing socioeconomic needs, such as reducing urban poverty. To what extent can social, economic and climate objectives be aligned? Focusing on Kolkata in India, we consider the economic case for low-carbon urban development, and assess whether this pathway could support wider social goals. We find that Kolkata could reduce its energy bill by 8.5 per cent and greenhouse gas emissions by 20.7 per cent in 2025, relative to business-as-usual trends, by exploiting readily available, economically attractive mitigation options. Some of these measures offer significant social benefits, particularly in terms of public health; others jeopardize low-income urban residents' livelihoods, housing and access to affordable services. Our findings demonstrate that municipal mitigation strategies need to be designed and delivered in collaboration with affected communities in order to minimize social costs and – possibly – achieve transformative change.

KEYWORDS climate change / co-benefits / energy / health / mitigation / pro-poor / urban development

I. INTRODUCTION

Economic growth and the accompanying urbanization are linked to rising energy consumption and production of greenhouse gas emissions. Although just over half the world's population lives in urban areas, this demographic accounts for 67–76 per cent of global energy use and 71–76 per cent of global energy-related emissions.⁽¹⁾ Continued population growth, rural–urban migration and the physical expansion of urban boundaries (to bring peri-urban areas into urban areas) are expected to add a further 2.5 billion people to the world's urban population, with just three countries – India, China and Nigeria – accounting for 37 per cent of this growth.⁽²⁾ These trends are likely to increase the share of energy use and emission production taking place in urban areas. Cities in low- and lower-middle income countries therefore have to play a leading role in climate change mitigation to avoid a global temperature rise greater than 1.5°C.

There is growing recognition of the importance of cities as climate actors: notably, the Paris Agreement explicitly welcomes the efforts of

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cities to address and respond to climate change.⁽³⁾ Yet the opportunities facing individual cities vary immensely depending on their rate of population growth, geography and climate, urban morphology, socio-cultural aspirations, governance capabilities, and success in sustaining existing businesses and attracting new investments.⁽⁴⁾ Mature cities typically have large stocks of capital infrastructure that will need to be upgraded and retrofitted over coming decades to reduce emissions, particularly where transport systems are car-dependent and buildings are not energy-efficient. Cities with rapid population, economic and/or spatial growth must invest in new infrastructure in order to meet emerging demand and address the deficiencies in infrastructure faced by current populations. These investments provide opportunities to promote more energy-efficient urban forms and functions.⁽⁵⁾

Fast-growing megacities face both challenges simultaneously. Their city centres are likely to have well-established infrastructure, which will require significant retrofitting to improve their energy efficiency. However, there is also a need to manage urban development around the periphery of these megacities to ensure that new infrastructure is low-carbon and climate-resilient (among other social and environmental objectives). Almost all fast-growing megacities are in Asia, including Karachi, Shenzhen, Bangkok, Dhaka, Delhi and Jakarta.⁽⁶⁾

In megacities in low- and lower-middle income countries, climate mitigation is typically a secondary consideration. With over a billion people worldwide living in informal settlements, city governments may focus on economic growth or immediate social needs, such as reducing urban poverty. Where climate change is considered, adaptation is often prioritized over mitigation. Cities can be (and often are) hotspots of climate vulnerability due to the concentration of people, infrastructure and economic activity.⁽⁷⁾ Many Asian megacities are also in floodplains and deltas, and are consequently extremely exposed to the impacts of climate-related hazards, such as sea level rise, cyclones, storm surges and flooding.⁽⁸⁾ Low-income urban residents are particularly susceptible to the impacts of climate change, as they are more likely to live in areas with high exposure to risk, such as floodplains and steep slopes, and to lack access to basic infrastructure and services that could ameliorate that risk, such as drains and sewers.⁽⁹⁾ Given these people's minor contribution to global emissions, and the major challenges they face in reducing urban poverty and risk, there is a question as to whether low- and lower-middle income cities should bear any of the costs of climate mitigation.⁽¹⁰⁾

Yet, as highlighted above, cities need to pursue low-emission forms of urban development if the world is to avoid dangerous levels of climate change. Ensuring the energy and carbon efficiency of urban areas in the medium to long term depends significantly on decisions made in the short term. Fast-growing urban areas that are planning significant investment in capital infrastructure face "lock-in" and "path dependencies", whereby early decisions (or non-decisions) about land use, transport networks and technological options drive energy-intensive modes of social and economic activity for decades to come.⁽¹¹⁾ Many cities – including some in low- and lower-middle income countries – are accordingly establishing ambitious targets for emission reduction, climate-compatible development and green growth. It is essential that low-emission objectives are factored into these urban plans and policies in ways that do not compromise poverty reduction or climate adaptation. Yet the potential for conflicts between

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these objectives is currently underappreciated. Indeed, it is often assumed that the differences between climate change mitigation and adaptation measures, and measures to promote development and alleviate poverty, are relatively minor.⁽¹²⁾

In this paper, we present the economic case for a rapidly growing megacity in the developing world to integrate climate mitigation objectives into its development strategy, and assess whether these investments could support wider social goals. As outlined in Section III, we adopt a bottom-up approach, conducting a cost–benefit analysis of individual low-emission options to identify those with a positive net present value over their lifetime. In Section IV, we present the aggregate economic case and the energy/carbon savings from deploying this bundle of measures. In Section V, we evaluate some of the most significant interventions to determine their potential impacts on urban poverty and vulnerability. We draw on these results in Section VI to explore whether a transition to lower-emission forms of urban development can also promote more socially just and inclusive outcomes. However, first we introduce the case study: Kolkata in India.

II. CASE STUDY: KOLKATA, INDIA

Urban areas in India are projected to grow by 404 million people between 2014 and 2050.⁽¹³⁾ This equates to almost a million people each month for 35 years. Economic growth and the accompanying urbanization are having far-reaching effects on energy demand in India, particularly through rising ownership of appliances and vehicles, improved access to modern energy and growing demand for construction materials.⁽¹⁴⁾ Energy use in India has doubled since 2000, but per capita consumption remains only one-third of the global average.⁽¹⁵⁾ This figure conceals significant inequalities: 240 million (mostly rural) Indians lack access to electricity, but even those connected to the grid experience very uneven quality of service, particularly in informal settlements around the periphery of the cities.⁽¹⁶⁾

Kolkata, located in the state of West Bengal, is the third largest city in India and the 14th largest urban area in the world, with an estimated population of 14.9 million in 2015.⁽¹⁷⁾ Different parts of the city are experiencing different rates of population growth: while the 2011 census found that the population of the district of Kolkata declined by 1.67 per cent between 2001 and 2011,⁽¹⁸⁾ it increased by 6.29 per cent in the Kolkata Metropolitan Area (KMA – the focus of our study), which includes the suburbs that have grown around the original Kolkata district.

Manufacturing and the associated jobs are increasingly based in the periphery of the city, a phenomenon also observed in the Indian cities of Delhi, Chennai, Mumbai, Ahmedabad, Hyderabad and Bangalore.⁽¹⁹⁾ Although industry remains significant, Kolkata’s economy is highly diversified, serving as the financial and commercial hub for the Eastern region.⁽²⁰⁾ The city enjoys sustained economic growth – in FY2013–14, the city’s real per capita GDP grew by 4.7 per cent.⁽²¹⁾ Wider Kolkata is therefore experiencing rapid spatial and economic expansion, while the metropolitan heart of the city is also experiencing population growth.

Yet poverty remains endemic. Around one-third of Kolkata’s population lives in informal settlements. Although four-fifths of urban residents in Kolkata had access to piped drinking water at the time of the

last National Family Health Survey, only half had access to improved toilet facilities and only 59 per cent used modern energy (liquefied petroleum gas, natural gas, electricity or biogas): the remainder depended on kerosene and solid fuels such as coal and charcoal.⁽²²⁾ Most low-income households depend on the informal urban economy for jobs and livelihoods. Many live on land to which they have no legal claim or in houses that are not in compliance with building regulations. Conventional urban planning has excluded these informal sectors or sought to formalize them – in the process, often deepening poverty by destroying livelihoods and shelters.⁽²³⁾ Although there is some evidence that government agencies in Indian cities have utilized informality, and the resulting ambiguities around land use and ownership, to further their own urban development agenda,⁽²⁴⁾ there is also evidence that municipal authorities in Kolkata and other Indian cities are experimenting with more inclusive forms of urban planning and policymaking.

Kolkata has a tropical climate, with monthly mean temperatures varying from 19 to 30°C. Most rainfall occurs during the monsoon season between June and September. The city frequently experiences flooding during this time due to the inadequate drainage and sewer networks, which do not serve the city's whole population. Where this infrastructure exists, it is often a century old and lacks the capacity to meet the current population's needs.⁽²⁵⁾ The frequency and severity of these floods is likely to increase as the climate changes, particularly due to storm surges, sea level rise and more intense precipitation. "Future proofing" Kolkata against climate change, population growth and economic development is an immense challenge, particularly considering the scale of poverty and informality in the city.

III. METHODS

This paper evaluates the implications of "business-as-usual" modes of development for Kolkata's energy use, energy bills and greenhouse gas emissions in the period to 2025. It also evaluates a wide range of energy efficiency, renewable energy and other mitigation measures in terms of their economic feasibility and emission reductions. The results are drawn together to consider the case for investment in, and the energy and carbon implications of, the widespread deployment of low-emission measures in the city.

We collected data on the levels and the composition of energy demand in Kolkata for the housing, commercial buildings, transport and industry sectors. We also evaluated the electricity and waste sectors, both of which have implications for the emission intensity of Kolkata's development. For each of these sectors, and for the city as a whole, we used these historical data to develop "business-as-usual" baselines that project these trends through to 2025. These baselines allowed us to predict future levels and forms of energy supply and demand, as well as future energy bills and greenhouse gas emissions. We compared all future activities against the baselines. Data sources and assumptions used to establish these baselines are listed in the online supplement (Appendix B1); see Table 1 for a list of all information in the online appendices.

We developed lists of the energy efficiency, small-scale renewable energy, and other low-emission measures that could potentially be adopted

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TABLE 1
Information in online appendices

Appendix	Content
A	List of participants in focus group discussions
B1	Data sources and assumptions used to develop the business-as-usual (baseline) scenario
B2	Data sources and assumptions used to evaluate the economic feasibility and mitigation potential of each measure
C1	League table ranking the mitigation options available to Kolkata in order of cost-effectiveness (net present value per tonne of carbon dioxide equivalent [US\$/tCO ₂ -e])
C2	League table ranking the mitigation options available to Kolkata in order of mitigation potential (kilotonne of carbon dioxide equivalent [ktCO ₂ -e])

in each sector. We include both technological and behavioural measures. We calculated the net present value of each measure using data from the academic and grey literatures, with the inputs examined in a series of focus group discussions in Kolkata. In our assessment, we considered the capital, running and maintenance costs of each measure, focusing on the marginal or extra costs of adopting a more energy-efficient or lower-emission alternative. We then conducted an assessment of the likely savings of each option over its lifetime, taking into account installation and performance gaps. We used a real interest rate of 5 per cent to estimate the net present value, which was deemed by the focus groups to be a realistic long-term borrowing rate after adjusting for inflation. As each measure could be in place for many years, we accounted for changing carbon intensities of energy use with different levels of investment in the electricity sector. From 2015 to 2025, we assumed an average annual rise of 3 per cent in real energy prices.

We calculated the potential for deployment of each measure to 2025, not only for the sectors as a whole, but also for sub-sectors, taking into account the scope for change in households with different income levels and forms of energy consumption, or the scope for an option to be adopted in a particular industrial sub-sector. These assessments also considered the rates of change and growth in the relevant sectors of the city, as well as the lifespans and replacement rates of existing measures that could be replaced with more energy-efficient or lower-emission alternatives. Again, we subjected our assessments of the rates of deployment to participatory review in focus group discussions to ensure that they were as realistic as possible. These focus groups included representatives from energy utilities, the municipal corporations, state government, private companies and universities based in Kolkata. The full list of participants is provided in the online supplement (Appendix A).

Finally, we drew together our assessment of the performance and scope for deployment of each measure to calculate the aggregate investment needs and payback periods at the city scale, as well as impacts on energy supply and demand. The resulting economic case is presented from the perspective of the city as a unit, rather than from the perspective of

individual or institutional investors. The performance of some measures depends on whether and to what extent another option is also adopted. For example, the carbon savings from any measure depend on the carbon intensity of electricity supply, and this in turn depends on whether various low-carbon measures have been adopted in the electricity supply sector. To take these interactions into account, we calculated the effect of each measure on the potential energy savings of other measures to estimate their combined impacts. For example, any electricity savings from efficiency improvements in the housing sector are deducted from the emission reductions associated with reducing the carbon intensity of the grid. Data sources and assumptions used to determine the economic feasibility and mitigation potential of the different scenarios are listed in the online supplement (Appendix B2).

IV. ECONOMIC APPRAISAL

a. The impacts of continuing “business-as-usual” development

We find that Kolkata’s GDP in 2014 was INR 1.84 trillion (US\$ 31.5 billion), and if recent trends continue we forecast that GDP will grow to INR 4.4 trillion (US\$ 75.2 billion) by 2025. We also find that the total energy bill for Kolkata in 2014 was INR 169.2 billion (US\$ 2.9 billion), which indicates that 9.1 per cent of all income earned in Kolkata is currently spent on energy.

“Business-as-usual” trends in Kolkata show a rapid decoupling of economic output and energy use between 2000 and 2025 (Figure 1). However, GDP and energy demand per capita are both rising steadily, while the population of the metropolitan area is also growing. These effects are outpacing background improvements in energy efficiency and leading to a net increase in aggregate energy use. With increasing energy consumption and a projected increase in real energy prices of 3 per cent per annum, this would lead the total energy bill for Kolkata to more than double its 2014 level by 2025 in a business-as-usual scenario.

There is sufficient capacity in existing coal-fired power stations in West Bengal to meet anticipated electricity demand to 2025. With no plan to substantially decarbonize the electricity sector, the emission intensity of energy production is projected to remain largely constant until 2025. But increasing energy efficiency in the wider economy means that the emissions produced per unit of GDP will fall dramatically between 2000 and 2025 (Figure 2). It is important to note that, despite declining emission intensity per unit of GDP, rapid economic growth will cause both emissions per capita and total emissions to continue to rise. In a business-as-usual scenario, total emissions from Kolkata are forecast to increase by 54.0 per cent against 2014 levels by 2025.

Our analysis of business-as-usual trends in energy use and greenhouse gas emissions in Kolkata highlights the relative importance of improving efficiency on the one hand and of economic and population growth on the other. We see that energy use and greenhouse gas emissions per unit of GDP have halved in the last decade, and we predict that a continuation of recent trends would see them halve again by 2025. This is an impressive rate of relative decoupling, particularly compared to India’s national target of reducing emission intensity of GDP by 20–25 per cent by 2020, relative

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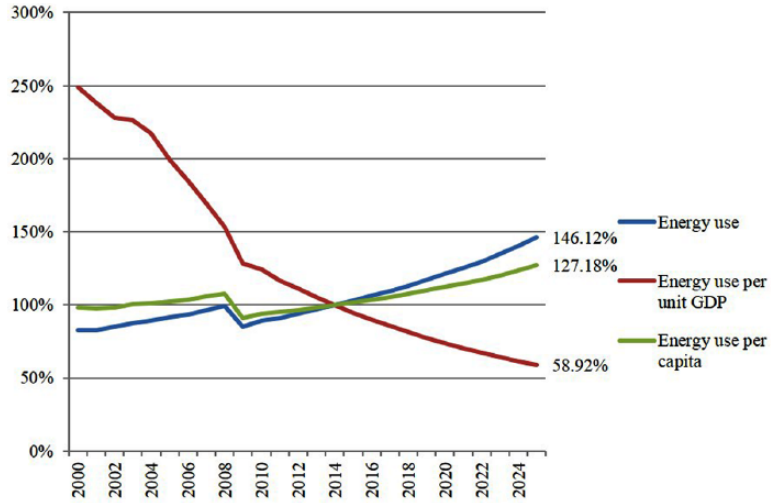


FIGURE 1
Indexed energy use in the business-as-usual scenario – total, per unit of GDP, and per capita (2014=100)

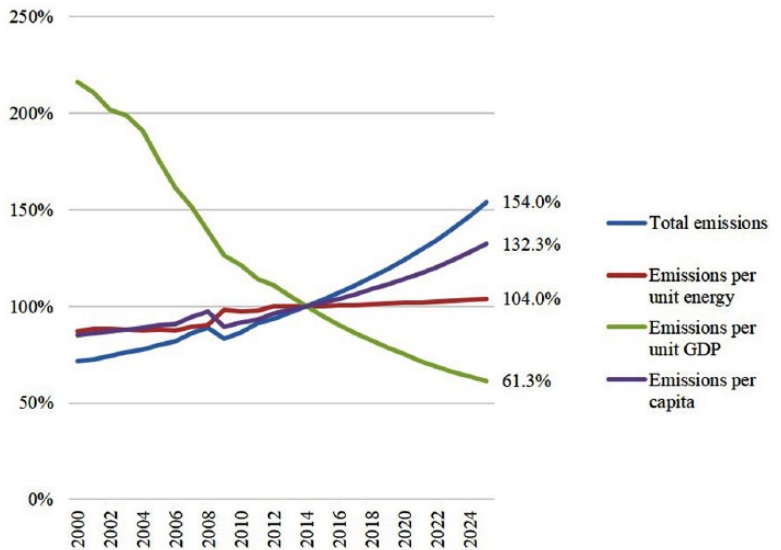


FIGURE 2
Indexed greenhouse gas emissions in the business-as-usual scenario – total, per unit of energy, per unit of GDP, and per capita (2014=100)

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to 2005 levels.⁽²⁶⁾ However, we also see that any benefits from this relative decoupling will be more than offset by the impacts of rapid economic and population growth in the KMA: between 2014 and 2025, energy use will increase by 46.1 per cent and greenhouse gas emissions by 54.0 per cent.

b. Potential economic and emission savings

We identify a wide range of energy efficiency, renewable energy and waste management measures available to Kolkata that could significantly impact on the race between efficiency and growth. The most cost- and emission-effective measures in each sector are presented in Table 2. The economic and carbon savings of the full list of measures are provided in the online supplement (Appendices C1 and C2).

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TABLE 2
The potential economic returns and emission reductions associated with specified low-emission measures

Sector	Measure ^(a)	Economic savings (US\$/tCO ₂)	Emission reductions (ktCO ₂ -e)
Electricity	Coal retrofit (6,045 MW)	71	61,435 ^(b)
Electricity	Solar photovoltaics (900 MW)	-18	14,083 ^(b)
Commercial and public buildings	Ban on incandescent light bulbs	80	477
Commercial and public buildings	Green building standards (100 per cent of new buildings)	0	6,768
Residential buildings	Ban on incandescent light bulbs	57	1,426
Residential buildings	Air conditioners: 40 per cent improvement in average energy efficiency by 2025	39	6,003
Industry	Basic metals and fabrication: waste heat recovery (oil-fired melting)	383	4
Industry	Non-metallic processing: natural gas turbines for electricity generation and use of exhaust flue gas of turbines in spray dryers	137	2,318
Transport	Parking demand management	1,380	1,138
Transport	Commercial vehicle efficiency standards (introduction in 2018)	276	1,933
Waste	Improved recycling	4	226
Waste	Gasification	2	1,618

NOTES:

^(a)The economic savings reflect the net present value of the measure (at an annual discount rate of 5 per cent) over its lifetime, divided by the estimated emissions reduction. The emission reductions are calculated for the period 2015–2025 inclusive. This table does not consider the economic impact of enabling policies, such as feed-in tariffs or carbon pricing.

^(b)These savings would be across the grid, which serves the whole state of West Bengal; only 18.3 per cent would be attributed to the city of Kolkata.

We find that Kolkata could reduce the projected increase in greenhouse gas emissions in 2025 by:

- 20.7 per cent, relative to business-as-usual levels, through economically attractive investments in the city, i.e. through measures that would pay for themselves and generate a real return above 5 per cent per annum over their lifetime. This is the cost-effective scenario in Figure 3. It would require an investment of INR 119.3 billion (US\$ 2.0 billion), generating annual savings of INR 30.4 billion (US\$ 520.7 million), paying back the investment in 3.9 years and generating annual savings for the lifetime of the measures.
- 22.1 per cent, relative to business-as-usual levels, with economically attractive investments in large-scale renewable electricity generation infrastructure, in addition to the above investments in other sectors. This is the cost-effective (electricity) scenario in Figure 3. It would require an investment of INR 39.7 billion (US\$ 679.0 million), generating annual savings of INR 18.2 billion (US\$ 311.8 million), paying back the investment in 2.2 years and generating annual savings for the lifetime of the measures.
- 35.9 per cent, relative to business-as-usual levels, with economically neutral measures, i.e. measures that could be paid for by re-investing the income generated from the bundle of economically attractive measures available to the city. These measures do not individually have a positive net present value when a discount rate of 5 per cent is used, but their costs could be more than covered through the return from the economically attractive investments. This is the cost-neutral scenario in Figure 3. It would require an investment of INR 205.6 billion (US\$ 3.6 billion), generating annual cost savings of INR 33.5 billion (US\$ 573.6 million) and paying back the investment in 6.2 years.
- 38.7 per cent, relative to business-as-usual levels, with economically neutral measures in large-scale renewable electricity generation infrastructure, i.e. measures that could be paid for by re-investing the income generated from the bundle of economically attractive measures available to the electricity utility. This is the cost-neutral (electricity) scenario in Figure 3. It would require an investment of INR 210.4 billion (US\$ 3.6 billion), generating annual cost savings of INR 27.0 billion (US\$ 462.0 million), paying back the investment in 7.9 years and generating annual savings for the lifetime of the measures.

The impacts of these different scenarios on the city's greenhouse emissions are shown in Figure 3. Even with significant increases in population and energy consumption over the coming decade, these results suggest that the Kolkata Metropolitan Area could reduce its greenhouse gas emissions in absolute terms at no net cost to the city. Moreover, the measures identified in this study do not entail significant changes to the city's spatial layout or economic composition. More ambitious public transport interventions or green economy programmes could further reduce the emission intensity of urban development in cities like Kolkata.

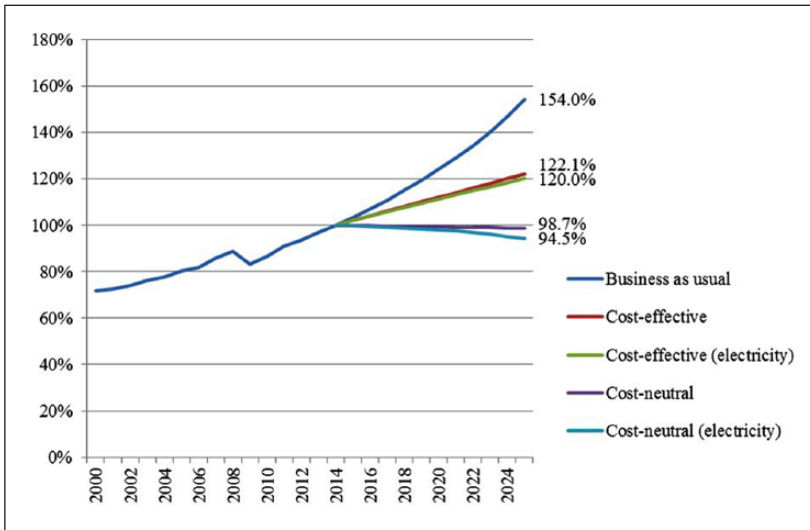


FIGURE 3

Emissions from Kolkata under five different scenarios between 2000 and 2025 (2014=100)

NOTES:

The measures in the cost-effective scenarios each generate a return of at least 5 per cent per annum. The costs of measures in the cost-neutral scenarios could be covered by the returns generated from the cost-effective scenarios.

V. SOCIAL AND ENVIRONMENTAL APPRAISAL

The most economically attractive low-emission measures available to Kolkata are predominantly in the industry and transport sectors: notable examples include parking demand management, vehicle efficiency standards, and phasing in of compressed natural gas (CNG) buses to replace the existing fleet. However, the most significant opportunities for emission reduction are in electricity generation, housing, commercial buildings and (proportionate to its share of the city’s greenhouse gas emissions) solid waste management. Measures with large mitigation potential include retrofitting of coal-fired power plants, more efficient air conditioners and gasification.

Some of these measures will have large co-benefits or co-costs that need to be taken into account. In these cases, the implications for urban greenhouse gas emissions will likely be subordinate to other considerations, particularly where investments have a transformative effect on urban form and function. For example, there is strong evidence that urban sprawl and low population density increase per capita transport and household energy use, as they lead to greater dependence on private cars and proportionately higher heating and cooling demand.⁽²⁷⁾ Yet investments in public transport or policies regarding building height or floor area ratios are unlikely to be influenced by emission reduction targets compared to local issues, such as air pollution, congestion, road

27. See reference 10, Dodman (2009); also Romero Lankao, P, J L Tribbia and D Nychka (2009), “Testing theories to explore the drivers of cities’ atmospheric emissions”, *Ambio* Vol 38, No 4, pages 236–244.

safety, house prices and cultural norms. We therefore assess the impacts of some of the economically attractive low-emission measures available in Kolkata to determine whether they align with wider social objectives.

a. The waste sector

Like most cities in low- and lower-middle income countries, Kolkata's waste sector produces a significant share of the city's greenhouse gas emissions, primarily in the form of methane. This waste is substantially disposed of through dumping, an undesirable option in waste handling hierarchy. Waste-to-energy is widely considered an attractive solution from a mitigation perspective, as it not only reduces the emissions associated with the decomposition of organic waste but also displaces fossil fuels as a source of energy. The sale of the energy generated can also help to cover the costs of waste management. In Kolkata, we identify gasification as a particularly economically attractive option; in other cities of low- and lower-middle income countries, landfill gas utilization, incineration with electricity recovery, and anaerobic digestion are more financially viable.⁽²⁸⁾

One estimate suggests that up to 2 per cent of the population in the global South may rely on waste picking or scavenging for their livelihoods.⁽²⁹⁾ In India, that equates to over 25 million people – more than the population of Australia. Waste pickers and itinerant waste buyers face significant discrimination and severe, adverse health effects due to this work, yet they provide a valuable service. Waste picking reduces the quantity of waste that needs to be collected, thereby lessening the public costs of waste management and the public health risks of inadequate collection. Waste picking is also a highly efficient way of recycling.⁽³⁰⁾ However, investments in capital-intensive waste-to-energy infrastructure can reduce the scope for waste picking: for example, incineration destroys waste in the process of generating energy, while landfill gas utilization can preclude waste picking because waste companies will cover landfills to improve the efficiency of gas collection. While attractive in terms of both the financial savings and emission reduction, waste-to-energy therefore risks undermining the livelihoods of low-income and other marginalized groups, thereby increasing their vulnerability to shocks and stressors.

Municipal solid waste management strategies therefore need to be designed and delivered in ways that support the informal sector in order to realize wider social and environmental benefits. In practice, the precondition for effectively including the informal sector has often been that waste pickers are organized into micro-enterprises, co-operatives or community-based organizations that collectively negotiate with business and government.⁽³¹⁾ The Alliance of Indian Waste Pickers (AIW) has been at the forefront of this, supporting its 35 member organizations to conduct advocacy campaigns, share learning, and support their peers to protect and improve their livelihoods. The successes of AIW demonstrate that waste-to-energy technologies can be integrated into urban solid waste management plans in ways that do not exacerbate poverty and vulnerability. For example, government agencies can encourage the public to separate their waste and sell it directly to itinerant waste buyers, and provide sanitary sites and equipment at disposal sites so that waste pickers can identify and extract waste with potential value.⁽³²⁾ The remainder can subsequently be used for energy generation.

28. Papargyropoulou, E, S Colenbrander, A H Sudmant, A Gouldson A and L C Tin (2015), "The economic case for low-carbon waste management in rapidly growing cities in the developing world: The case of Palembang, Indonesia", *Journal of Environmental Management* Vol 163, pages 11–19.

29. Medina, M (2007), *The World's Scavengers: Salvaging for Sustainable Consumption and Production*, AltaMira Press, Lanham, cited in Ezeah, C, J A Fazakerley and C L Roberts (2013), "Emerging trends in informal sector recycling in developing and transition countries", *Waste Management* Vol 33, No 11, pages 2509–2519.

30. Furedy, C and A Alamgir (1992), "Street pickers in Calcutta slums", *Environment and Urbanization* Vol 4, No 2, pages 54–59; also Wilson, D C, C Velis and C Cheeseman (2006), "Role of informal sector recycling in waste management in developing countries", *Habitat International* Vol 30, No 4, pages 797–808.

31. Ezeah, C, J A Fazakerley and C L Roberts (2013), "Emerging trends in informal sector recycling in developing and transition countries", *Waste Management* Vol 33, No 11, pages 2509–2519; also Gunsilius, E (2010), *Role of the informal sector in solid waste management and enabling*

During the focus group discussions, representatives from the Kolkata Metropolitan Development Authority highlighted successful attempts to formalize employment of informal waste pickers through cooperation with local non-government organizations and community-based groups. They argued that formalizing and collaborating with waste pickers had increased the effectiveness of newly provided waste separation infrastructure.⁽³³⁾ Thus, achieving the “best” economic and climate outcomes may be contingent on integrating low-emission measures with existing livelihoods and development projects.

b. The transport sector

India is home to many of the world’s most polluted cities: on the average day, urban residents in Delhi breathe in three times as many fine particles (PM2.5) as those in Beijing, and 15 times the maximum level recommended by the World Health Organization.⁽³⁴⁾ This air pollution is primarily produced by vehicles, construction activities, power plants, brick kilns, waste burning, and the combustion of oil, coal and biomass in households.⁽³⁵⁾

The substantial contribution of private cars and freight trucks to India’s urban air pollution exemplifies the inequalities within Indian cities. India currently has about 13 cars per thousand people, although rates of ownership are much higher in cities: Delhi, Chennai and Bangalore have 157, 127 and 185 cars per thousand people respectively.⁽³⁶⁾ Most of these cars are owned by relatively wealthy urban dwellers. Yet those who are most exposed to air pollution are low-income urban residents, who typically spend more of their time outdoors⁽³⁷⁾ and live in more polluted areas.⁽³⁸⁾ These people rarely own cars, but depend on non-motorized options or public transport.

Kolkata is unusual among India’s megacities for its relatively low levels of vehicle ownership (<40 cars per 1,000 people)⁽³⁹⁾ and well-developed public transport sector: almost 80 per cent of all trips are by some form of public transport, compared to 60 per cent of trips in Mumbai and 42 per cent in Delhi.⁽⁴⁰⁾ Nonetheless, with high rates of air pollution and road fatalities, there are opportunities to further improve the quality of the transport system. We identified a bundle of low-emission measures in the transport sector that are economically attractive when assessed at the city scale (Table 3). These interventions would also significantly improve air quality. Critically, most of the costs of these measures would be borne by the higher-income segments of the population, while most of the health benefits would be enjoyed by low-income urban residents who would otherwise be most exposed to air pollution.

This is not always the case, as illustrated by the focus group discussions about transport emission policy in Kolkata. In 2009/10, the city passed a law phasing out vehicles over 15 years old, primarily for air quality reasons. However, the distributional effects of this law varied, as the positive impact on public health was partially offset for drivers of such vehicles, whose livelihoods suffered as a result of this environmental regulation.⁽⁴¹⁾ In this case, environmental interventions urgently needed to be accompanied by social support to ensure that the costs were not disproportionately borne by a relatively vulnerable minority.

More ambitious measures, such as Bus Rapid Transport systems, cycling lanes and pedestrian sidewalks, do not prove economically

conditions for its integration – experiences from GTZ, Paper presented at Transwaste Workshop on the Informal Sector, Geneva, accessed 8 May 2016 at <http://www.transwaste.eu/file/001441.pdf>; and Kabeer, N, K Milward and R Sudarshan (2013), “Organising women workers in the informal economy”, *Gender and Development* Vol 21, No 2, pages 249–263.

32. Sharholi, M, K Ahmad, G Mahmood and R C Trivedi (2008), “Municipal solid waste management in Indian cities – A review”, *Waste Management* Vol 28, No 2, pages 459–467.

33. See also JICA (2009), *Ex Ante Evaluation of Kolkata Solid Waste Management Improvement Project*, Japan International Cooperation Agency, accessed 26 May 2016 at http://www.jica.go.jp/english/our_work/evaluation/oda_loan/economic_cooperation/c8h0vm000001rdjt-att/india09_2.pdf.

34. WHO (2014), *Public health, environmental and social determinants of health (PHE): Ambient (outdoor) air pollution in cities database 2014*, World Health Organization, accessed 7 May 2016 at http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/.

35. Guttikunda, S K, R Goel and P Pant (2014), “Nature of air pollution, emission sources, and management in the Indian cities”, *Atmospheric Environment* Vol 95, pages 501–510.

36. Ghate, A T and S Sunder (2014), *Proliferation of Cars in Indian Cities: Let Us Not Ape the West*, Energy Research Institute Policy Brief 12, Delhi.

37. Foster, A and N Kumar (2011), “Health effects of air quality regulations in Delhi, India”, *Atmospheric Environment* Vol 45, No 9, pages 1675–1683.

38. Garg, A (2011), “Pro-equity effects of ancillary benefits of climate change policies: A case study of human health impacts of outdoor air pollution in New Delhi”, *World Development* Vol 39, No 6, pages 1002–1025.

39. See reference 36.

40. Cervero, R (2013), "Linking urban transport and land use in developing countries", *The Journal of Land Use and Transport* Vol 6, No 1, pages 7–24.

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43. Hasan, A (2009), "Land, CBOs and the Karachi Circular Railway", *Environment and Urbanization* Vol 21, No 2, pages 331–345.

44. Rahman, M M, G D'Este and J Bunker (2009), "Is there a future for non-motorised public transport in Asia?", *Proceedings of the 8th International Conferences of the Eastern Asia Society for Transportation Studies*, Surabaya, 16–19 November.

TABLE 3
The potential economic returns and emission reductions associated with cost-effective low-emission transport measures

Measure	Emissions reduction (ktCO ₂ -e) ^(a)	Economic savings (US\$/tCO ₂) ^(b)
Commercial vehicle efficiency standards	1,933	276
Replacement of diesel buses with CNG buses	1,417	55
Parking demand management	1,138	1,380
Private car efficiency standards	370	4

NOTES:

^(a)The emissions reductions are calculated for the period 2015–2025 inclusive.

^(b)The economic savings reflect the net present value of the measure (at an annual discount rate of 5 per cent) over its lifetime.

attractive by the criterion used in this study: specifically, they do not generate energy savings or other financial returns of at least 5 per cent per annum. However, if implemented at scale, these interventions could offer significant health benefits by improving road safety, air quality and fitness, and provide substantial productivity benefits by enhancing access to employment, goods and services.⁽⁴²⁾ In the longer term, establishing mass transit and non-motorized transport networks can also promote densification of urban form around transport nodes or social/economic activities. This enables cities to reduce per capita transport energy use compared to that consumed with sprawling, car-based forms of urban development. Although difficult to quantify, these economic benefits are substantial.

However, all these measures need to consider the social risks of new infrastructure development, and ensure that pro-poor strategies are mainstreamed into construction and operation. In particular, there are significant risks that residents of informal settlements will be evicted;⁽⁴³⁾ that providers of transport services, such as rickshaw or taxi drivers, will lose their jobs;⁽⁴⁴⁾ and that public transport systems will either not serve or be unaffordable for low-income groups, who will continue to depend on walking, cycling and informal providers.⁽⁴⁵⁾ Government agencies and private companies responsible for designing and implementing transport infrastructure can mitigate these risks through, for example, subsidizing bus fares for low-income groups or providing skill development opportunities for informal transport providers so that they can develop new livelihoods.

Case studies suggest that low-income and other marginalized groups need to be meaningfully involved in transport planning if new infrastructure is to redress growing social and environmental inequalities. In Karachi, for example, Hasan⁽⁴⁶⁾ describes how the residents of informal settlements organized as part of the All Pakistan Alliance for Katchi Abadis. By documenting the history of the residents and the spatial layout of the

settlements, this community-based organization was able to negotiate with the government to change proposed upgrades to the Karachi Circular Railway. The aim was not to block much-needed investment in public transport, but to ensure that new infrastructure was constructed without unnecessary evictions and that residents who were relocated did not become poorer as a result. In India, the National Slum Dwellers Association, Mahila Milan and SPARC have had similar achievements in fighting evictions and organizing voluntary community resettlements to ensure that the construction of new urban infrastructure did not destroy livelihoods or exacerbate vulnerability.⁽⁴⁷⁾

c. The electricity sector

Like most cities, Kolkata is served by a regional grid, so decisions about the composition of electricity supply are made beyond the city boundaries. Yet the choices have huge ramifications for the city. We calculated that the coal-based West Bengal grid currently produces 1.5 tCO₂-e/MWh; for reference, the average emission intensity of electricity in India is 0.82 tCO₂-e/MWh,⁽⁴⁸⁾ while global best practice from this grade of coal generates less than 0.75 tCO₂-e/MWh.⁽⁴⁹⁾ Reducing the emission intensity of electricity production would significantly broaden the range of low-emission options that could be adopted in Kolkata. Under present conditions, for example, switching from diesel to electric vehicles is technically feasible, but would lead to a net increase in greenhouse gas emissions despite the inefficiency of many diesel engines.

We find that retrofitting West Bengal's coal-fired power plants to improve their efficiency could save 61.4 MtCO₂-e, while investing in solar photovoltaics and wind could save 14.1 MtCO₂-e and 8.4 MtCO₂-e respectively (although only 18.3 per cent of this emission reduction would be attributed to Kolkata). From an economic perspective, only coal retrofits satisfied our requirement that the investment should cover its own costs and generate a return of 5 per cent or more per annum. Without enabling policies, solar and wind both fell short. In this case, government policies – such as reducing customs and excise duties for renewables, imposing a cess on coal and adopting net metering – have helped to align economic and climate objectives,⁽⁵⁰⁾ and the economics of wind and solar are rapidly improving in India, as elsewhere.⁽⁵¹⁾

Even if wind and solar investments prove competitive over the medium to long term, these options typically entail higher capital costs than fossil fuel-based alternatives.⁽⁵²⁾ This means that decision-makers must consider the opportunity costs of the incremental investment in electricity generation: Could these resources be better spent on (for example) the provision of sanitation infrastructure or health care? Even assuming that these resources are available only to the electricity utilities, would they be more appropriately used to extend the grid to unserved informal settlements? During the focus group discussions, power industry representatives questioned the distributional effects of higher capital spending on renewables, the cost of which would be passed to all consumers and would increase pressure on utilities to clamp down on illegal electricity theft. Such electricity theft often allows low-income households and residents of informal settlements to access modern energy.⁽⁵³⁾ In other words, decision-makers in the electricity sector must weigh a marginal lessening of global climate change against the benefits

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46. See reference 43.

47. Patel, S, C d'Cruz and S Burra (2002), "Beyond evictions in a global city: people-managed resettlement in Mumbai", *Environment and Urbanization* Vol 14, No 1, pages 159–172.

48. Bhawan, S and R K Puram (2014), *CO₂ Baseline Database for the Indian Power Sector*, Central Electricity Authority, Ministry of Power, Government of India, accessed 28 May 2016 at <http://www.indiaenvironmentportal.org.in/files/file/CO2%20Baseline%20Database%20for%20the%20Indian%20Power%20Sector.pdf>.

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51. Kar, S K and A Sharma (2016), "Wind power developments in India", *Renewable and Sustainable Energy Reviews* Vol 48, pages 264–275; also Rohankar, N, A K Jain, O P Nangia and P Dwivedi (2016), "A study of existing solar power policy framework in India for viability of the solar projects perspective", *Renewable and Sustainable Energy Reviews* Vol 56, pages 510–518.

52. Jacobs, M (2012), "Climate policy: Deadline 2015", *Nature*

Vol 481, No 7380, pages 137–138; also Schmidt, T S (2014), “Low-carbon investment risks and de-risking”, *Nature Climate Change* Vol 4, pages 237–239.

53. Baruah, B (2010), “Energy services for the urban poor: NGO participation in slum electrification in India”, *Environment and Planning C: Government and Policy* Vol 28, No 6, pages 1011–1027.

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55. Mimmi, L M (2014), “From informal to authorized electricity service in urban slums: Findings from a household level survey in Mumbai”, *Energy for Sustainable Development* Vol 21, pages 66–80; also Parikh, P, S Chaturvedi and G George (2012), “Empowering change: The effects of energy provision on individual aspirations in slum communities”, *Energy Policy* Vol 50, pages 477–485.

56. Modi, V, S McDade, D Lallement and J Saghir (2006), *Energy and the Millennium Development Goals*, Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project and World Bank, New York, accessed 28 May 2016 at http://www.unmillenniumproject.org/documents/MP_Energy_Low_Res.pdf.

associated with electricity access, such as increased labour productivity due to the use of machinery or better public health due to reduced indoor air pollution and incidence of burns.⁽⁵⁴⁾

The tension between poverty reduction and climate mitigation can be reduced to the higher upfront costs of low-carbon electricity options. Over a longer time horizon, renewables prove increasingly economically attractive – particularly after factoring in the social costs of air pollution and the financial risks of fossil fuel price volatility. This is an ideal opportunity to use climate finance to shift the costs of low-emission urban development, either temporally or geographically. If the Green Climate Fund, the Global Environmental Facility or a similar institution covered the incremental cost of solar or wind in West Bengal, it would deliver significant emission reductions of grid power compared to the business-as-usual scenario of new coal-fired power plants. Reducing the carbon intensity of electricity could also have a multiplier effect on the city’s emissions by increasing the feasibility of other low-emission measures, such as fuel switching. Finally, this use of climate finance would deliver significant positive spillovers, such as improving ambient air quality and building local capacities in installing and maintaining renewable energy systems.

A more nuanced analysis of the electricity sector suggests that there are major political economy barriers to the provision of low-carbon electricity, particularly to informal settlements. In the focus group discussions, representatives of the power sector suggested that, without policy mandates, utilities are reluctant to challenge the economic status quo by seeking alternatives to low-quality domestic coal or promoting the use of renewables at the expense of coal-fired power plants. A large body of evidence also demonstrates that utilities are reluctant to work with informal settlements to overcome barriers such as lack of formal tenure, high upfront costs, complex bureaucratic processes, and the vested interests of some business and community leaders, who may profit from informality.⁽⁵⁵⁾

A range of approaches are being trialled to tackle these obstacles. In some cities, non-governmental organizations and community-based groups have driven changes in utility policies and practices to make electricity more easily accessible: the work of the Mahila Housing SEWA Trust in Ahmedabad is one such example. In Kolkata, public–private partnerships are pushing this agenda for informal settlements or rooftop solar programmes. However, in most cases, these obstacles force low-income urban residents to either use illegal electricity connections or to depend on more expensive, carbon-intensive alternatives such as kerosene. Affordable and reliable electricity is essential for both social and economic development, enhancing both quality of life and productivity.⁽⁵⁶⁾ This suggests that significant changes to governance and financing arrangements are required in order to enable a transition towards pro-poor, climate-friendly electricity supply.

VI. DISCUSSION AND CONCLUSIONS

If Kolkata continues along its current development path to 2025, the city will see per capita energy use rise by 27.2 per cent and per capita emissions by 32.3 per cent, relative to 2014 levels. When these trends are combined

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with population growth, the city's energy use will grow by 46.1 per cent, its greenhouse gas emissions by 54.0 per cent and its energy bill by 111.6 per cent over the same period. These increases are expected to take place despite significant background improvements in energy efficiency.

In this study, we identify a bundle of mitigation measures that could help to shift Kolkata onto a less emission-intensive development path. By investing in economically attractive measures within the city, Kolkata could reduce its energy expenditure by 8.5 per cent and its greenhouse gas emissions by 20.7 per cent relative to business-as-usual trends. Re-investing the profits from these measures in additional low-emission measures would allow the city to maintain its greenhouse gas emissions roughly at 2014 levels, despite significant population and economic growth. Reducing the carbon intensity of electricity supply would further lower emissions from the city, as well as increase the scope for additional low-emission measures such as electric vehicles. Realizing these opportunities would require investment of US\$ 3.6 billion in the city and US\$ 462.0 million in the electricity sector, but the investments would pay for themselves in 6.2 years and 7.9 years respectively – and continue to generate savings over their lifespan. These are immense economic savings and emission reductions, particularly considering that this study focused on readily available mitigation options rather than more complex changes to urban form and function, such as transit-oriented development, which were beyond the scope of this methodology. While maintaining a low-emission development trajectory may require ambitious structural change in the longer term, these results suggest that, in the medium term, megacities such as Kolkata may be able to avoid emission increases at no net cost.

The economic case for low-emission development presented in this paper is significant from a social perspective, as it demonstrates that Kolkata and cities like it could reap considerable financial benefits by pursuing less emission-intensive development trajectories. What is less clear is whether the wider impacts of low-emission urban development will necessarily be positive. The introduction of new technologies, such as energy-from-waste, can destroy urban livelihoods such as waste picking; new energy-efficient infrastructure, such as high-rise buildings or public transport, can lead to the demolition of informal settlements, displacing low-income and other marginalized urban dwellers. Even where mitigation actions generate positive co-benefits for low-income groups, the higher investment needs associated with climate-friendly options create significant opportunity costs that are particularly problematic in the context of endemic urban poverty. So can low-emission development be pro-poor?

Based on assessments of the electricity, transport and waste sectors, it is apparent that low-emission options could reduce urban poverty and vulnerability relative to conventional measures. In particular, large-scale deployment of renewable energy and energy efficiency measures could reduce the chronic air pollution in Indian cities, which primarily affects the health of low-income urban residents who have higher rates of exposure. Climate finance can play an important role in facilitating these investments by covering the incremental investment needs associated with low-carbon options, thereby reducing the opportunity costs associated with these options.

However, the sector studies referenced in Section V demonstrate that urban planners and policymakers need to work closely with affected communities to ensure that low-emission interventions do not compound

57. See reference 43; also see reference 47; Boonyabancha, S and D Mitlin (2012), "Urban poverty reduction: learning by doing in Asia", *Environment and Urbanization* Vol 24, No 2, pages 403–421; d'Cruz, C and P Mudimu (2013), "Community savings that mobilize federations, build women's leadership and support slum upgrading", *Environment and Urbanization* Vol 25, No 1, pages 31–45; and Papeleas, R, O Bagotlo and S Boonyabancha (2012), "A conversation about change-making by communities: some experiences from ACCA", *Environment and Urbanization* Vol 24, No 2, pages 463–480.

58. See reference 47; also see reference 57, d'Cruz and Mudimu (2013).

59. Ayers, J (2011), "Resolving the adaptation paradox: Exploring the potential for deliberative adaptation policy-making in Bangladesh", *Global Environmental Politics* Vol 11, No 1, pages 62–88; also Dobson, S, H Nyamweru and D Dodman (2015), "Local and participatory approaches to building resilience in informal settlements in Uganda", *Environment and Urbanization* Vol 27, No 2, pages 605–620.

60. Archer, D, F Almansi, M DiGregorio, D Roberts, D Sharma and D Syam (2014), "Moving towards inclusive urban adaptation: approaches to integrating community-based adaptation to climate change at city and national scale", *Climate and Development* Vol 6, No 4, pages 345–356; also Fenton, A, D Gallagher, H Wright, S Huq and C Nyandiga (2014), "Up-scaling finance for community-based adaptation", *Climate and Development* Vol 6, No 4, pages 388–397.

61. Tyler, S and M Moench (2012), "A framework for urban climate resilience", *Climate and Development* Vol 4, No 4, pages 311–326.

social conflict, poverty and vulnerability. Previous research in India and elsewhere suggests that involving low-income urban residents can be particularly effective when communities are organized.⁽⁵⁷⁾ Partnerships with organized communities can also allow municipal, state and national governments to achieve more transformative urban change, both to reduce the emission intensity of urban development and to enhance the climate resilience of vulnerable urban residents. Community-based organizations facilitate collective action, which can ensure that ambitious mitigation and adaptation measures, such as densification or relocation of informal settlements, are implemented in ways that safeguard urban livelihoods and access to basic services and infrastructure.⁽⁵⁸⁾ This will be essential if megacities with rapid population, economic and spatial growth (such as Dhaka, Jakarta or Kolkata) are to promote energy-efficient spatial forms around their periphery.

Community-based organizations also provide a channel to share information between urban residents and local authorities. This provides an avenue for government actors to raise awareness about opportunities to reduce energy bills and ways to respond to climate risks,⁽⁵⁹⁾ as well as for residents of informal settlements to ensure that their needs and priorities are effectively incorporated into urban planning and investments. This allows decision-makers to reduce poverty and vulnerability in a targeted way.⁽⁶⁰⁾ Above all, partnerships between governments and community-based organizations can ensure that low-income and other vulnerable groups have opportunities to influence and shape urban politics and processes. This can shift norms around participation and accountability so that the interests of affected communities are factored into decision-making processes.⁽⁶¹⁾ Such partnerships can therefore achieve a transformative impact by tackling the drivers of urban poverty and vulnerability: marginalization, exclusion and inequality.

This study of Kolkata demonstrates that there are many economically attractive low-emission measures available to the city. Even without considering ambitious land use planning measures, the aggregate mitigation potential of this bundle of measures is significant and demonstrates that there is significant scope for Asian megacities to shift to less emission-intensive development paths without necessarily undertaking structural change in the short term. Critically, many of these measures also offer substantial co-benefits that could contribute to poverty reduction and improved climate resilience. It is therefore essential that decision-makers place issues of equity and inclusivity at the centre of urban policymaking and planning to ensure that the pursuit of economic growth and low-emission development does not exacerbate urban poverty and vulnerability.

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