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Research paper

## Cities and climate change mitigation: Economic opportunities and governance challenges in Asia



Andy Gouldson<sup>a,c</sup>, Sarah Colenbrander<sup>a</sup>, Andrew Sudmant<sup>a</sup>, Effie Papargyropoulou<sup>b</sup>, Niall Kerr<sup>a</sup>, Faye McAnulla<sup>a</sup>, Stephen Hall<sup>a</sup>

<sup>a</sup> ESRC Centre for Climate Change Economics and Policy, School of Earth and Environment, University of Leeds, UK

<sup>b</sup> Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia, Malaysia

<sup>c</sup> Corresponding author at: School of Earth and Environment, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK

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### ABSTRACT

Cities are central to the fight against climate change, but the IPCC recently noted that many cities – and particularly those in the developing world – lack the institutional, financial and technical capacities needed to switch to low emission development paths. Based on detailed case studies of three Asian cities, this paper finds that the adoption of low emission development strategies (LEDS) at the urban level could be economically attractive. However, it also argues that without a coordinated multi-level, cross-sectoral governance framework these opportunities for low carbon urban development are likely to be left unexploited. As these governance conditions are frequently not in place, we argue that these case study cities, and cities in similar contexts, are likely to miss even the economically attractive low carbon development opportunities and become increasingly locked in to higher cost, higher carbon development paths. Due to their growing size and importance, we conclude that the presence or absence of governance arrangements that enable the adoption of low carbon development strategies in Asian cities will have global implications for climate change.

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## 1. Introduction

Cities must be central to global climate change mitigation and the adoption of low emission development strategies (LEDS). Urban areas are home to more than half of the world's population, are responsible for around three quarters of global energy use and energy-related greenhouse gas emissions and are growing rapidly (Gouldson et al., 2015; IPCC, 2014; UN DESA, 2014; WHO, 2014). However, the IPCC (2014) reports that many cities, and particularly those in the developing world, lack the political will and the institutional and financial capacities needed to shift to more energy and carbon-efficient development paths.

Many authors have emphasised the role that new governance arrangements could play in enabling urban-level responses to climate change (Acuto, 2013; Betsil & Bulkely, 2006; Corfee-Morlot et al., 2009; Franzén, 2013; Matsumoto et al., 2014; OECD, 2010). There has been a particular interest in multi-level governance arrangements that might improve the fit and the interplay between actors and institutions at the global, national, regional and local levels (Gouldson et al., 2015; Matsumoto et al., 2014; Paavola, Gouldson, & Klavankova-Oravska, 2009). Effective multi-level interactions across these scales are needed because urban action on climate change is partly determined by policies

and mechanisms introduced at higher scales – city plans are often adopted to contribute to national climate mitigation strategies that are themselves established in response to international frameworks and agreements (Anguelovski & Carmin, 2011; Franzén, 2013; Schreurs, 2010).

Arguably, the cross-sectoral aspects of climate governance are equally important at the city scale. Although some authors have explored the potential for integrating climate policy goals into sectors such as energy, transport or housing at the national level (c.f. Adelle & Russel, 2013), there have been very few analyses of the need for such cross-sectoral coordination at the urban level. Without such coordination, climate policy may be left in the domain of relatively weak environment departments and overlooked by the frequently more powerful and better-resourced departments in municipal government. The 'mainstreaming' of climate goals into the key areas of urban policy is therefore critically important.

With the exception of China (c.f. Balme & Yi, 2014), Asian cities have been largely neglected in research on governance for climate mitigation. This is an important gap in light of Asia's immense importance to climate change mitigation efforts. Asia contributed 27% of global emissions in 2011, or 30% if emissions from land use change and forestry are included (WRI, 2014); moreover, its contribution to global emissions is expected to increase significantly in the coming years in both absolute and relative terms (IEA, 2013). The forecast increase in energy use and

E-mail address: [a.gouldson@leeds.ac.uk](mailto:a.gouldson@leeds.ac.uk) (A. Gouldson).

carbon emissions from Asia largely relates to expected levels of economic and population growth that will be concentrated in urban centres. Cities in Asia are projected to absorb an additional billion people over the next twenty-five years, which will demand huge investment in housing, energy, transport and waste infrastructure (Puppim de Oliveira et al., 2013). These investments provide an opportunity to pursue aggressive urban LEDS – failing to take these opportunities will lead to further lock in to costly, carbon-intensive development modes. The urban planning decisions – or, in the many instances of unplanned or ungoverned urban development, the ‘non-decisions’ (Crenson, 1971) – made during this period are therefore critically important.

This paper explores the scope and options for urban LEDS in Asia by examining opportunities for low carbon development in three cities: Kolkata in India, Palembang in Indonesia and Johor Bahru in Malaysia. These case study cities are not necessarily representative – they were selected as they have been the focus of in-depth studies by the authors on the economic case for low carbon investment – but understanding trends and opportunities in these cities can generate insights that have a wider relevance, particularly for other cities that are in comparable development contexts or that are facing similar governance challenges within Asia. Key data for the three cities are provided in Table 1.

The paper is structured as follows. In the next section, we outline the methodology used to identify trends in energy use and carbon emissions and to evaluate the economic case for and potential impacts of low carbon investment at the urban level. We then introduce the three case studies. For each, we consider the relationship between different levels of governance in each country, current patterns in energy use and greenhouse gas (GHG) emissions, and the opportunities for cost effective low carbon investment. We also discuss the cross-sectoral nature of the challenge by highlighting the distribution of low carbon development opportunities across sectors. We then compare the findings for each city, and identify some of the barriers to the adoption of urban LEDS. This underpins a discussion about mechanisms to improve coordination across different levels of governance and to mainstream climate considerations into different spheres of policymaking. We conclude by reflecting on the importance of building multi-level, cross-sectoral climate governance frameworks if Asian cities are to adopt and pursue urban LEDS.

## 2. Cases, approach and methods

A common methodology was adopted across the three case studies. The methodology has three stages:

1. An assessment of trends in energy use and GHG emissions between 2000 and 2013 and of the implications of these trends continuing to 2025.
2. An analysis of the scope for economically attractive low carbon investments in the electricity sectors serving each city over the next decade (2015–2025), developed from a bottom-up evaluation of a wide range of low carbon electricity generation measures.
3. An analysis of the scope for economically attractive low carbon investments in different sectors over the next decade (2015–2025), developed from a bottom-up evaluation of a wide range of climate mitigation measures.

**Table 1**  
Key statistics for the cities of Kolkata, Palembang and Johor Bahru in 2014.

	Kolkata, India	Palembang, Indonesia	Johor Bahru, Malaysia
Population	14.7 million	1.5 million	1.8 million
GDP per capita (USD)	2139	2940	14,790
Energy use per capita (kgoe)	243	861	2862
Emissions per capita (tCO <sub>2</sub> -e)	1.69	1.98	11.55
Energy bill (% of GDP)	9.1%	18.7%	15.2%

Each of the studies considered energy use and emissions from the metropolitan area, including those from direct consumption of fuels and waste facilities within local authorities' reach (so-called Scope 1 emissions) and those produced while generating the electricity consumed within the city (Scope 2 emissions). The studies therefore took into account the energy mix, carbon intensity and the production and transmission efficiencies of electricity supply. Due to lack of data, none of the studies considered emissions from industrial processes (typically included in Scope 1). We also did not include embedded energy or carbon in the goods or services produced or consumed within the city (Scope 3 emissions) due to the methodological complexities highlighted by Macrotullio et al., (2012). Other research has found that accounting for embedded energy through consumption-based carbon accounts is likely to reduce the carbon footprint of producer and exporter cities and to increase the carbon footprint of consumer and importer cities (Satterthwaite, 2008; Hoornweg et al., 2011; Gouldson et al., 2015). The extent of the adjustments that would be required if embedded energy was taken into account is not clear, but due to the industrial and export-oriented nature of the economies within which our case study cities exist, it is likely our estimates of per capita emissions would be lower if Scope 3 emissions were included (Davis & Caldeira, 2010).

Trends in energy use and emissions between 2000 and 2013 were used to forecast trends to 2025. These projections assume that no additional climate and energy policies are introduced in this period, apart from planned investments in electricity generation, transmission and distribution, which are accounted for in the changing carbon intensity of electricity between 2015 and 2025. The studies therefore assume that growth in the different cities can continue in the near future as it has in the recent past: for example, we project a consistent relationship between growth in income per capita and rising levels of vehicle ownership and use. In practice, many cities might encounter structural limits to growth such as gridlock in the transport system.

Longlists of low carbon measures that could be adopted in the housing, non-domestic buildings, transport, industry and waste sectors were then prepared for each city through extensive reviews of the academic, policy and grey literatures.<sup>1</sup> These lists included measures for the household and non-residential buildings sectors including small-scale renewables, improved building standards and more energy efficient heating/cooling, lighting and appliances. For the transport sector they included measures such as enhanced provision of different forms of public and non-motorised transport and the adoption of more fuel-efficient vehicles. For industry, a wide range of energy efficiency measures was included and for the waste sector measures such as enhanced recycling and methane capture from landfill sites were considered. To turn these longlists into shortlists, a process of iterative participatory appraisal was utilised (see Fraser, Dougill, Mabee, Reed, & McAlpine, 2006) with stakeholder panels selecting the measures that were appropriate to local conditions in each of the three cities.<sup>2</sup>

Preliminary estimates of the lifetime costs and benefits (expressed as a net present value (NPV) calculation) of each shortlisted measure were then generated using estimates derived from the grey and academic literature on its technical and economic performance. This economic analysis considered only the private financial costs and benefits of deployment in each context, comprising lifetime capital, running and maintenance costs, compared with Business as Usual (BAU) practice. Again adopting a process of iterated participatory appraisal, these estimates were reviewed and refined by stakeholder groups to ensure that they were locally appropriate and as realistic and accurate as possible. We adopted a standard real interest rate of 5% and assumed an annual increase of 3% in real energy prices. Prices for measures were held constant (at 2014 levels) without taking technological learning in the low carbon sector into account, thereby making the

<sup>1</sup> The data sources used in the three studies are presented in Appendix A.

<sup>2</sup> Full lists of the participants in the stakeholder panels that were drawn on in each of the three cities are detailed in Appendix B.

estimates of economic and environmental performance of the measures more conservative.

The estimates of GHG mitigation potential for each shortlisted measure were based on avoided emissions from substituting renewable energy for fossil fuel generation, energy demand reduction through efficiency improvements, or waste emissions avoided, relative to BAU levels. We evaluated the potential scope for deploying each of the measures in the various sectors in the period to 2025 based on low carbon programmes in comparable cities and consultations with local authorities. These assessments took into account the life spans and replacement rates of existing systems, which offer scopes to substitute more energy or carbon-efficient alternatives, and also rates of change and growth in the relevant sectors of the city. The estimated scopes for deployment were subject to participatory review in expert workshops.

Finally, we drew together the results of our economic and carbon assessments to determine the potential impact of exploiting all of the cost effective measures (i.e. those with a positive NPV). These scenarios allowed us to understand overall investment needs and paybacks, as well as the potential emission reduction through the deployment of economically attractive options. In developing these scenarios, we recognise that some of the measures interact with each other so that their performance will depend on whether/to what extent another option is also adopted. For example, the carbon savings from more efficient air conditioners depend on whether there are green building standards in place. When we were determining the potential savings across a sector or across the city economy, we calculated the effect of each measure on the potential energy savings of other measures to develop realistic assessment of their combined impacts. For example, any carbon savings from more efficient air conditioners are deducted from the emission reductions associated with green building standards.

### 2.1. Case study 1 – India and Kolkata

India has the largest aggregate energy demand in the world after China and the United States, and demand is rising rapidly (Ahn & Graczyk, 2012). However, per capita energy consumption in India remains low. Though Indian energy is relatively carbon-intensive, per capita emissions are only one third of the world and 14% of the OECD averages (Ahn & Graczyk, 2012).

In international climate negotiations, India asserts that it must be able to increase energy use per capita – and correspondingly, its absolute levels of carbon emissions – to achieve inclusive growth and eliminate poverty. Even so, the Government of India announced in 2010 that it would endeavour to reduce the (non-agricultural) emission intensity of its GDP by 20–25% by 2020 in comparison to the 2005 level. India's new willingness to set climate targets was influenced by growing energy security concerns, increasing opportunities to access international climate finance, growing public awareness of climate change vulnerability, the priorities of new political leadership and international pressure (Isaksen & Stokke, 2014; Michaelowa & Michaelowa, 2012; Thaker & Leiserowitz, 2014).

At the national level, India's National Action Plan on Climate Change explicitly focuses on development needs with 'co-benefits for addressing climate change', emphasising the relative importance of economic growth for domestic policymakers (Atteridge, Shrivastava, Pahuja, & Upadhyay, 2012). The Plan outlines eight climate strategies of which four promote mitigation: (1) the National Solar Mission; (2) National Mission on Enhanced Energy Efficiency; (3) the National Mission on Sustainable Habitat; and (4) the National Mission for a Green India (Government of India, 2008). The National Action Plan remains the guiding document for Indian climate policy (Pahuja, Pandey, Mandal, & Bandyopadhyay, 2014), although the Five Year Plans effectively update the policies and targets. The current Five Year Plan establishes, for instance, additional renewable energy capacity targets of 13 GW of hydropower, 5.3 GW of nuclear capacity, 15 GW of wind and 10 GW of solar (Government of India, 2013).

While most states are establishing climate action plans in response to national directives, their ambition and effort varies substantially according to their development agenda, climate vulnerability and the economic opportunities associated with mitigation (Atteridge et al., 2012). State-level participation in national schemes is also uneven: for example, many states have not established credible renewable energy targets despite a national goal of 15% (Shrimali, Tirumalachetty, & Nelson, 2012), while the Energy Conservation Building Code has only been implemented in 8 of 29 states (Pahuja et al., 2014).

Different institutions are responsible for coordinating climate policy in each state, including the Department of Science and Technology, the State Pollution Control Boards and the Department of Environment. These differences naturally shape the policy focus and instruments adopted in each state (Atteridge et al., 2012). Climate change policies still tend to overwhelmingly be sector-based rather than cross-sectoral. For example, only a few local authorities have integrated climate considerations into spatial planning in Indian cities (Kumar & Geneletti, 2015).

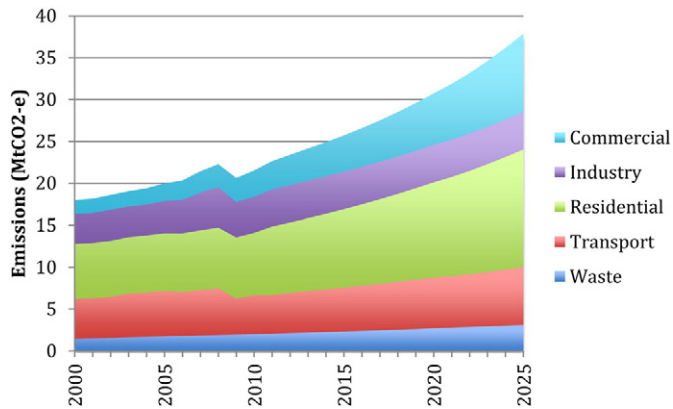
Our case study city, Kolkata is the third largest city in India (Demographia, 2013), with a population of 14.1 million in 2011 (Chandramouli, 2011). Although it is the economic hub of the Eastern Region, there are stark inequalities in the city: one third of the population lives in slums (Ghosh, 2013), where inhabitants lack access to grid electricity, clean water, sanitation or adequate housing. Population density reaches 23,149 people/km<sup>2</sup> in parts of the city (KMDA, 2007).

At the state level, the West Bengal Government has actively decentralised governance to local councils, increasing the scope for the Kolkata Municipal Development Agency to plan and manage urban development. The focus in the City Development Plan is on expanding housing through the construction of townships and tackling congestion by building expressways and transit corridors (KMDA, 2007). Despite Kolkata's vulnerability to climate change (particularly rising sea levels and more extreme weather), mitigation and adaptation have not meaningfully been mainstreamed into spatial planning compared with other megacities in India such as Mumbai and Delhi (Kumar & Geneletti, 2015). The West Bengal State Climate Change Action Plan (Government of West Bengal, 2012) remains the authoritative climate policy document for the city.

Within Kolkata, we find that emission intensity of GDP will fall by 35.2% between 2005 and 2020 – substantially higher than India's national target of 20–25% during the same period, and by 45% between 2005 and 2025. However, these relative benefits will be outweighed by the absolute impacts of ongoing population and economic growth in the coming years. We find that total GHG emissions from the city grew by 38.5% between 2000 and 2014, and will grow by a further 52.0% (relative to 2014 levels) by 2025 under BAU conditions. With industrial development deliberately limited within the city boundaries, the most significant source of consumption and growth is the residential sector (see Fig. 1).

The electricity supplied to Kolkata comes primarily from low-grade coal generation with highly inefficient transmission and distribution systems. This means that electricity is highly carbon-intensive – emission levels are ~1.5 tCO<sub>2</sub>/MWh, double best practice generation from this type of coal (IEA, 2010). Some improvements in the carbon intensity of electricity supplied to Kolkata are possible through investments in electricity systems. We estimate that retrofitting 6045 MW of coal-fired power generation in West Bengal could reduce emissions from the grid by 11.6% by 2025 relative to BAU levels. Although we predict that this would require investments of INR39.7 billion (USD679 million), these would generate annual savings of INR18.2 billion (USD311.8 million) thereby paying for themselves in c.2 years.

At the city level, we find that Kolkata could reduce its carbon emissions by 20.7% in 2025 relative to BAU levels through economically attractive investments within the city. This would require an investment of INR119.3 billion (USD2.0 billion), which would generate annual savings of INR30.4 billion (USD0.52 billion). This package of investments



**Fig. 1.** Emissions (MtCO<sub>2</sub>-e) by sector for Kolkata, India, between 2000 and 2025. The pronounced drop in emissions in 2008–2009 is partially a function of the global financial crisis and partially a function of new regulation requiring vehicles over fifteen years old to be taken off the road.

would pay for itself in 3 years and continue to generate annual savings for the lifetime of the measures. While most of the economic savings identified were in the transport sectors – demand management and vehicle efficiency standards in particular – substantial carbon savings were available in all sectors. Green building standards, more efficient appliances and retrofitting residential buildings all proved to have significant mitigation potential.

## 2.2. Case study 2 – Indonesia and Palembang

If emissions from land use change and forestry are taken into account, Indonesia is one of the largest GHG emitters in the world (National Climate Change Commission, 2010). Although it has the fourth largest population, Indonesia's energy demand is the sixteenth largest in the world. This illustrates both relatively low levels of energy consumption per capita (18% of the OECD average) and the significant potential for Indonesia's energy-related GHG emissions to increase with population and economic growth.

Recent criticism of Indonesia's weak forest governance and opportunities for international funding has led it to assume a relatively proactive role in global climate negotiations (Resosudarmo, Ardiansyah, & Napitupulu, 2013). It was among the first developing countries to pledge emission reductions, committing at the Copenhagen Conference of Parties "to materialise 26 to 41% CO<sub>2</sub> equivalent emission reduction" by 2020, relative to BAU levels (Government of Indonesia, 2010). Indonesia's focus has been on reducing emissions from deforestation and forest degradation where it has large opportunities to attract international finance and technical assistance (National Climate Change Commission, 2010). The international community and national government have relatively neglected the massive increase in energy-related emissions in Indonesia over the last decade (Resosudarmo et al., 2013).

At the national level, implementation of climate plans has been lagging, partially due to competition among government ministries (Resosudarmo et al., 2013). Regarding non-forestry emissions, the Ministry of Environment, National Commission on Climate Change and National Development Planning Agency all have legitimate claims to lead cross-sectoral mitigation activities (Resosudarmo et al., 2013), while the Ministries of Finance, Industry, Public Works and Transport also have important roles to play (Murtiningtyas, 2012).

The energy sector is guided by the Energy Mix Policy, which sets a target of 15% renewable energy generation by 2025. The National Energy Agency has proposed to increase this to 25% by 2025 (Jupesta et al., 2011), although this target includes 'new energy' such as coal liquefaction and gasification (Director General of New and Renewable Energy and Energy Conservation, 2011). Despite these targets, national

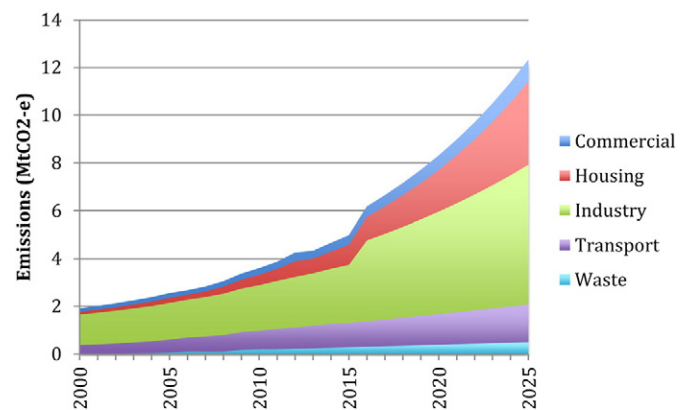
policies continue to favour high carbon energy. Subsidies for diesel, kerosene and electricity continue, despite reforms to gasoline subsidies (Sambijantoro, 2015), and regulatory frameworks continue to favour coal over geothermal options (Smith, 2012).

It is widely understood that, if Indonesia is to achieve its emission reduction targets, it will do so through improved forest governance rather than by pursuing more carbon-efficient forms of urban or industrial development. However, provinces in Indonesia are expected to develop local Action Plans for Reducing Greenhouse Gas Emissions that align with the national Action Plan, but are tailored to local resources, opportunities and vulnerabilities. With the finalisation of these local Action Plans, and with climate change issues mainstreamed into provincial development plans, local authorities will be responsible for implementation. National government agencies envision themselves providing overall coordination, technical assistance and capacity development (Murtiningtyas, 2012).

Sub-nationally, although Jakarta dominates the political and economic landscape, Indonesia has thirteen cities with populations from 1 to 3 million. The relatively small populations and infrastructure deficits facing these cities may offer their local authorities more scope to pursue urban LEDS than Indonesia's single megacity. With its population of 1.5 million, our case study city of Palembang is representative of many of these second-tier cities. It is the capital of the state of South Sumatra and a major port, and industrial hub for Indonesia. Significant industries include textiles, wood and paper products, chemicals and pharmaceuticals, rubber and plastic products, fabricated metals, and machinery. While its economy is growing at rates of 6–7%, access to electricity is unreliable, and consumption per capita remains low. Rapid industrialisation combined with a growing vehicle fleet means that air pollution and congestion pose severe problems.

Palembang is seeking national and international support to pursue more sustainable development trajectories. The city has been selected by the Ministry of Transport as one of three cities to showcase sustainable transport options. The city council is collaborating with German Federal Enterprise for International Cooperation (GIZ) to reduce air pollution and with the Japan International Cooperation Agency (JICA) to improve solid waste management. The city council is therefore already seeking to mainstream environmental issues into development planning.

Within Palembang, per capita energy consumption has been growing steadily in recent years, and is expected to accelerate between 2014 and 2025. When combined with rapid economic growth, particularly in the industrial sector, this means that emissions from Palembang have increased by 143.8% between 2000 and 2014, and are expected to increase by a further 164.6% (relative to 2014 levels) in the period to 2025 if BAU trends continue (see Fig. 2). However, these increases will be outstripped by economic growth: we project that the emission



**Fig. 2.** Emissions (MtCO<sub>2</sub>-e) by sector for Palembang, Indonesia, between 2000 and 2025. The dramatic increase in industrial emissions in 2015–2016 is based on the anticipated completion of a new fertiliser factory in the city.

intensity of economic activity will fall by 64.5% between 2000 and 2025 (Colenbrander et al., 2015a).

To some extent, anticipated growth in emissions could be mitigated through state-level investments in the electricity sector. Analysis of the economic options for this sector suggest that it would be possible to install 1000 MW of geothermal power and to retrofit 514 MW of natural gas-fired power plants in Sumatra. This would reduce emissions from the grid by 12.2% by 2025 (relative to BAU levels). This would require an investment of IDR35.0 trillion (USD2.9 billion), generating annual savings of IDR2.3 trillion (USD175 million) so that the investments would pay back in just over 15 years.

There is scope for proportionately larger emission reductions through urban action. We find that Palembang could reduce its carbon emissions by 24.1% in 2025 relative to BAU levels through economically attractive investments. This would require an investment of IDR4.77 trillion (USD405.6 million), which would generate annual savings of IDR5.14 trillion (USD436.80 million). The package of investments would therefore pay for themselves in less than one year and continue to generate annual savings for the lifetime of the measures. Nearly half of this mitigation potential is in the industrial sector, where different forms of fuel switching are among the most cost and carbon-effective options. However, to encourage industry to move away from carbon-intensive diesel-powered electricity generation will require the provision of more reliable electricity supplies and this is largely outside of the influence of the city itself. Subsidy reform proved very economically attractive – although this could only be delivered by the national government – while energy-from-waste options proved highly carbon-effective.

### 2.3. Case study 3 – Malaysia and Johor Bahru

Malaysia's energy demand tripled between 1990 and 2010 so that it now has the second highest energy demand per capita in Southeast Asia after Brunei. Relatively high energy consumption per capita combined with relatively carbon-intensive energy means that although its GDP is c.60% of the OECD average its per capita carbon emissions are 76% of the OECD average (World Bank, 2015).

In international negotiations on climate change, Malaysia has voluntarily committed to reduce the emission intensity of GDP by up to 40% based on 2005 levels by 2020. However, the Malaysian government has explicitly emphasised that any improvements in the emission intensity of GDP are conditional on technology transfer and financial support from Annex I countries, and that climate action is secondary to continued development (Ministry of Natural Resources and Environment, 2010: XIV).

Malaysia's stance on climate change is significant because it is arguably the most economically advanced of the rapidly industrialising countries in Southeast Asia. There is therefore a risk that its large and fast-growing neighbours (Indonesia, Thailand and Vietnam) will emulate its energy- and carbon-intensive development path. Malaysia's reluctance to take a leadership role in international climate negotiations may be attributed in part to its large fossil fuel reserves. Oil-related revenue contributed 40% of total government revenue in 2010 (Economic Planning Unit, 2010), and the country is projected to remain a net oil and gas exporter until 2035 (Rahim & Liwan, 2012).

Domestically, Malaysia is currently expanding electricity generation capacity in order to meet growing demand, with significant planned investments in coal-fired and nuclear power plants (Khor & Lalchang, 2014). While energy efficiency and renewable energy are relatively cost effective, the government is not meaningfully pursuing these options (Oh, Lalchand, & Chua, 2014). Instead, Malaysia maintained generous subsidies for fossil fuels until 2014, which reduced the incentives to conserve energy or invest in clean energy.

The current Malaysia Plan (2011–2015) establishes or maintains a number of national low carbon programmes. These include a renewable energy target of 985 MW by 2015 (5.5% of installed capacity), facilitated

by a feed-in tariff; an energy efficiency target of 4000 ktoe per year by 2015, prioritising more efficient lighting, appliances and buildings; and the construction of energy-from-waste infrastructure (Economic Planning Unit, 2010). Mitigation measures are therefore sectorally focused (Khailani & Perera, 2013) and insignificant relative to, for example, the expansion of installed coal-fired capacity by 3.4 GW between 2008 and 2013 (Oh et al., 2014).

At a local scale, urban development in Malaysia is governed by the Federal Department of Town and County Planning, while most mitigation actions are sectoral and directed by the relevant government agency. Local action plans must align with state and national plans (Khailani & Perera, 2013). The centralised governance structures mean that low carbon action at a local or regional level is often driven by the national government: for example, the cities of Putrajaya and Cyberjaya have been developed by national government to showcase low carbon cities in Malaysia (Ministry of Energy, Green Technology and Water, 2012).

Several Malaysian cities and regions are pursuing climate mitigation actions within the frameworks of the National Physical Plan and State Structure Plan (Ho, Matsuoka, Simson, & Gomi, 2013). Foremost among these is the Iskandar Malaysia Special Economic Corridor, which has set an emission intensity reduction target of 50% by 2025 relative to 2005 levels (UTM, IRDA, & Kyoto University, Okayama University, National Institute for Environmental Studies, 2012). The cities of Johor Bahru and Pasir Gudang are 'flagship zones' in Iskandar Malaysia. These closely linked cities had a combined population of 1.8 million in 2014, growing at approximately 4% per year (AECOM, 2009). Manufacturing contributes 45% of GDP in the Southern Johor Economic Corridor, dominated by the electrical and electronics, petro- and oleo-chemical and agro-processing industries (IRDA, 2006). Johor Bahru is also emerging as a commercial and services centre, while Pasir Gudang is an important port.

Within Johor Bahru, our analysis suggests that the city will cut the carbon intensity of GDP by 69.8% between 2000 and 2025 under BAU conditions, outstripping regional or national targets. However, despite improvements in emission intensity, we find that the absolute level of emissions produced by Johor Bahru increased by 317.6% between 2005 and 2014, and will increase by a further 83.8% (relative to 2014 levels) by 2025 if BAU trends continue (see Fig. 3) (Colenbrander et al., 2015b).

There is limited potential for emission reductions from electricity generation in Peninsular Malaysia as major investments in coal-fired electricity supply – with capacity to meet growing energy needs for many years – have already been made. However, we find that installing 600 MW of natural gas-fired power plants equipped with the best available technologies and replacing 2000 MW of natural gas and 120 MW of diesel power plants with solar photovoltaic panels would be cost effective. These measures would reduce

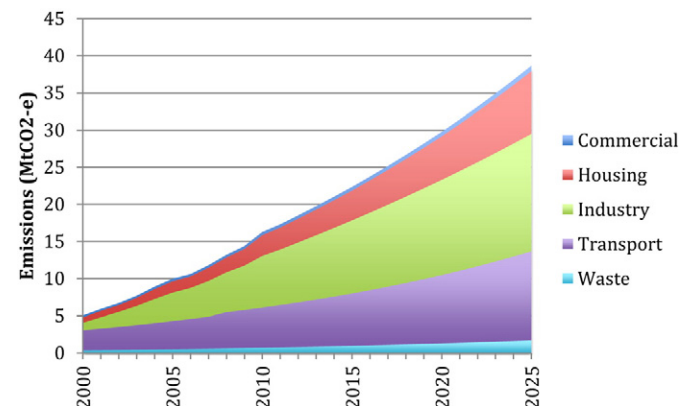


Fig. 3. Emissions (MtCO<sub>2</sub>-e) by sector for Johor Bahru, Malaysia, between 2000 and 2025.

emissions from the grid by 2% by 2025 (relative to BAU levels), require an investment of MYR23 billion (USD6.9 billion), generate annual savings of MYR1.9 million (US\$576 million) and pay back the investment in 12 years.

At the city level, we find a substantial scope to reduce emissions. Our analysis suggests that Johor Bahru could reduce its carbon emissions by 24.2% in 2025 (relative to BAU levels) through economically attractive investments. This would require an investment of MYR3.33 billion (USD1.01 billion), which would generate annual savings of MYR2.56 billion (USD0.77 billion). This package of investments would pay for itself in 1.3 years and continue to generate annual savings for the lifetime of the measure. Over half of the emission savings potential for Johor Bahru relate to the transport sector, where the most cost effective opportunities relate to the promotion of hybrid and more fuel-efficient vehicles and the adoption of new traffic management schemes. The most carbon-effective options relate to new fuel standards.

### 3. Comparative analysis and discussion

The analysis presented above shows that GHG emissions are rising rapidly in all three of the case study cities. Yet structural changes in the city economies and background trends in energy efficiency are leading to significant improvements in energy and carbon intensity. The Indian government has stated that it will endeavour to reduce the emission intensity of its GDP by 20–25% by 2020 in comparison with the 2005 level. This analysis shows that Kolkata will reduce its emission intensity by 35.2% over this period even under BAU conditions. Similarly, the Malaysian government has committed to reduce the emission intensity of GDP by up to 40% based on 2005 levels by 2020 while the analysis shows that Johor Bahru will reduce its emissions by 63.5% over this period under BAU conditions. Although the Indonesian government has not offered specific emission intensity reduction targets, Palembang is on track to reduce the carbon intensity of GDP by 30.9%. These city-level achievements under BAU conditions and without investment in low carbon measures such as those analysed above suggest that national climate commitments are readily achievable and lack ambition. Even if governments choose only to exploit those options that are economically attractive, our results demonstrate that there is a substantial scope to attain further improvements in carbon intensity by implementing LEDS in Asian cities.

In all three instances, cost effective low carbon options are readily apparent across the different sectors. In the electricity sector, the results show that there is untapped potential to decarbonise supply to each of the three case study cities. The unbroken lines in Fig. 4 show the carbon intensity of grid electricity consumed by each city under BAU conditions. It is apparent that there are no planned investments that will

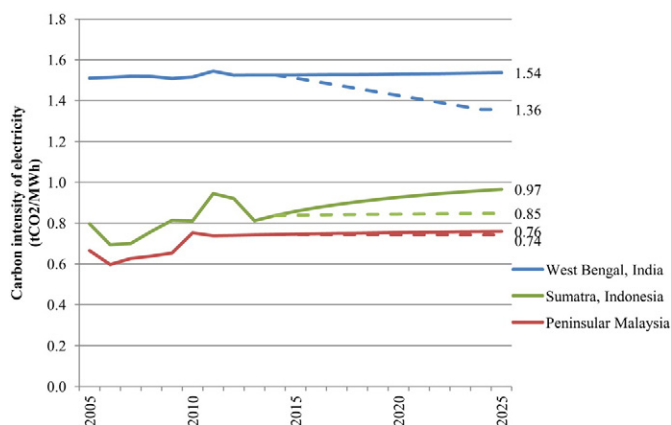


Fig. 4. The carbon intensity of the electricity grid serving each city between 2000 and 2025 under BAU conditions (unbroken line) and with the deployment of economically attractive low carbon measures (dashed line).

significantly reduce the carbon intensity of grid electricity in these cities, and that the expansion of coal-fired power plants supplying the Sumatra grid will actually increase the carbon intensity of electricity consumed in Palembang. However, the dashed lines in Fig. 4 show the potential carbon intensity of grid electricity with the implementation of economically attractive low carbon measures in the electricity sector. These investments would reduce emissions from electricity generation by 11% in West Bengal, 12% in Sumatra and 2% in Peninsula Malaysia. The provision of more reliable, lower carbon electricity would also enable cities in each region to explore a wider range of mitigation options. However, the governance arrangements that are needed to exploit these options are lacking in each context.

In Malaysia, delivering low carbon measures in the electricity sector would need coordinated action among four federal agencies and implementation by the utility company Tenaga Nasional Berhad (Chua & Oh, 2010). In Indonesia, the national Ministry of Energy and Mineral Resources and the state Ministry for Environment combine to govern the public electricity utility PLN (Indriyanto et al., 2006). In India, the electricity sector was historically the responsibility of vertically integrated state-owned monopolies such as the West Bengal State Electricity Board but recent reforms have shifted power to national policymakers (particularly the Ministry of Power) and regulators who oversee what are now disaggregated and liberalised energy markets. In all instances then, responsibilities are spread between different ministries and agencies and across multiple levels. Climate action for the electricity sector requires multi-level, inter-agency coordination.

Within the cities studied, our results also indicate that there is a significant scope to reduce carbon emissions (relative to BAU trends) through exploiting economically attractive low carbon options. As is shown in Fig. 5, the rate of increase of emissions from each city could be reduced significantly through cost effective options in the residential, commercial, transport, industry and waste sectors. The most economically attractive options in each city are presented in Table 2 – as can be seen they include a range of different measures that need to be applied across all of the different sectors.

To enable the widespread adoption of these measures, policy interventions are likely to be needed from national, state and local governments and from policy areas including energy, finance, housing, transport, land use planning and economic development. Raising awareness and securing support for the promotion of the different elements of LEDS from these multiple and at times competing policy domains are a major challenge in all contexts, but it is especially pronounced at the urban level in the contexts considered here. There are some instances where municipal governments have the powers needed to intervene effectively, but there are many others where the powers are absent, are under-developed or are diffused and fragmented.

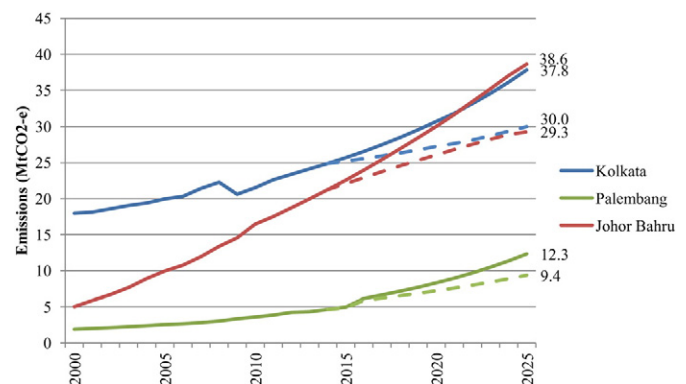


Fig. 5. GHG emissions from each city between 2000 and 2025 under BAU conditions (unbroken line) and with the deployment of economically attractive low carbon measures (dashed line).

**Table 2**  
The five most carbon-effective options in each city.

City	Measure <sup>b</sup>	Carbon savings (ktCO <sub>2</sub> -e)
Kolkata, India	Adopting green building standards for 100% of new buildings in the commercial	6768
	Deploying the most energy efficient air conditioners currently available in the domestic sector	6003
	Retrofitting fibreglass urethane roofs for 20% of existing households	4989
	Deploying more energy efficient air conditioners than BAU in the domestic sector	3688
	Deploying the most energy efficient entertainment appliances currently available in the domestic sector	3529
Palembang, Indonesia	Replacing diesel with biodiesel in industry	7048
	Supplementing diesel boilers with solar water heaters	6730
	Promoting landfill gas utilisation	3802
	Promoting energy-from-waste (combined heat and power)	3414
	Promoting energy efficiency in the fertiliser industry through steam reforming	3166
Johor Bahru, Malaysia	Replacing diesel with biodiesel in industry <sup>a</sup>	43,798

<sup>a</sup> Biofuel is assumed to be carbon-neutral in this analysis. This would demand effective supply chain management.

<sup>b</sup> Where two mutually exclusive options are among the top five, the less carbon-effective has been removed from this list.

In Johor Bahru, the importance of establishing enabling multi-level and cross-sectoral governance arrangements is especially apparent in the area of transport policy and planning. In Malaysia, as in many other contexts, only national government has the financial capacity and legislative authority to mandate or to offer either tax incentives to promote the up-take of more efficient or hybrid cars. Historically, however, transport policy at the national level in Malaysia has promoted vehicle sales in an effort to support the national automobile industry (Barter, 2004). Local and regional governments can lay the groundwork for investments in bicycle lanes or Bus Rapid Transport systems by conducting feasibility studies and preparing spatial plans, but individual authorities often do not have sufficient capacity or incentive to coordinate across metropolitan areas (OECD, 2014). While the five municipal authorities within Johor Bahru have completed a pioneering collaborative Local Plan, an integrated transport authority could enable new forms of policy and planning and help unlock new financial resources at the city scale (Hall & Jonas, 2014). The adoption of an integrated transport authority and the policy integration that it could enable would also require support from national government.

In Palembang, experiences in the waste sector highlight the need to consider broader governance capacities. Some of the most economically attractive low carbon measures, such as waste prevention and composting, require active support from non-state actors, particularly businesses and households if they are to be adopted. The ability of the severely resource constrained waste management department in the municipal government to engage and to secure such support is extremely limited. Other economically attractive measures, such as energy-from-waste and landfill gas utilisation, require significant upfront capital expenditure and close cooperation with the national electricity utility. As well as collaborating with state and national government within Indonesia, Palembang City Council has partnered with the Japan International Cooperation Agency to develop local ordinances and policy capacity for better waste management (JICA, 2015), and has established a landfill gas flaring project that generates carbon credits through the Clean Development Mechanism (CDM, 2009). This demonstrates how international multi-level governance and finance can help build the

institutional capacity to deliver LEDS at the local scale, whether through a regulatory or project-based approach.

In Kolkata, the municipal authorities and development agencies have been able to build institutional capacities for action in areas such as waste management as the powers in these areas were both devolved to the municipal level and concentrated in departments that were able to sign up to a low carbon agenda. In other areas though powers were spread across different departmental or functional boundaries, and path-dependencies meant that departments were more likely to support higher carbon than lower carbon development paths. In transport planning for example, ongoing commitments to road building limited the potential to support public and non-motorised transport modes more effectively. In other instances, most notably for electricity supply, the power to influence was not concentrated at the city scale, and municipal agencies depended on state and national level policies and wider market conditions over which they had very little influence. Multi-level governance arrangements were more of a top-down than a bottom-up nature and so the capacity to adopt key aspects of urban LEDS was restricted.

All of these examples show that cities alone frequently lack the capacity to push forward with climate change mitigation, even when there are significant co-benefits at the local level. In some instances, they might be able to 'cherry pick' particularly attractive and accessible low carbon measures that fall within the sphere of influence of a single department and that are relatively simple to implement. But their capacity to go further is frequently dependent on support from across municipal government, from higher levels of government and from non-state actors and agencies. In the absence of such governance arrangements, Asian cities such as those studied are likely to continue with business as usual modes of development, even when technically viable and economically attractive alternatives are readily available. This highlights the view that tackling climate change is a political and institutional rather than a technological or economic challenge.

#### 4. Conclusions

Given their growing scale and significance, Asian cities will have to be active in the global fight against climate change if it is to be effective. However, as is frequently the case in the global South, there are many other pressing priorities for local governments with limited resources and capacities. However, by focusing on three case study cities in Asia, we have highlighted the presence of substantial economic opportunities to deploy low carbon measures at the city scale. Municipal authorities therefore have a significant scope to pursue urban LEDS in ways that will also foster economic development. Moreover, low carbon initiatives at the city scale could generate knowledge and innovations that can have wider economic and social benefits, in addition to inspiring climate action in other cities and at a national scale. Whether cities exploit these opportunities depends significantly on the governance conditions that are in place. The multiple policy levers that need to be pulled to access these opportunities exist at different scales and in different sectors. Although the cities have some freedom to act, particularly in contexts of decentralised governance, their capacity to act could be significantly enhanced with more supportive and effective multi-level governance arrangements. Without more coordination between international, national, regional and local institutions, integration into different sectoral priorities and policies, and engagement between the public, private and civic sectors it seems likely that cities in Asia will lock in more fully to high-cost, high carbon development paths. Because of the global significance of Asian cities, this would substantially affect our collective ability to avoid dangerous levels of climate change.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.cities.2015.10.010>.

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