The Role of Industry in Forging Green Cities

MARCH 2015

Institute for
Industrial Productivity

Sharing best practices
for the low carbon future

iipnetwork.org

The Role of Industry in Forging Green Cities

MARCH 2015

Authors:
Chris Sall and Jigar V. Shah

Institute for Industrial Productivity

Table of Contents

List of Figures

1 Introduction

It is the age of the city. More than half of the world's population lives in cities and another 2.3 billion inhabitants are expected to join the urban population by 2050 at a rate of 1.3 million people per week (UN DESA 2014).

While the world's cities face an array of challenges and priorities — which are as diverse as the cities themselves — the need to establish a more sustainable footing for urban and peri-urban industry is common to many. Including industry in integrated strategies, policies, and planning to manage resource use will be crucial for these cities in the pursuit of greater environmental sustainability, as well as employment and improved living standards.

Broadly defined, sustainable and green cities are those that are committed to becoming more resource efficient, cleaner, and environmentally responsible while maximizing the economic and social benefits of their growth and improving the wellbeing of their current and future residents (see Hoornweg and Freire 2013; UNEP 2011).

This briefing note will make the case for why industry matters for sustainable, green cities and discuss what cities can do to promote industry that is both more productive and less resource intensive. Special attention is given to the need to more aggressively promote financially–attractive energy efficiency measures in industry that benefit both industry and society.

2 The footprint of industry in cities

Cities bring people, ideas, capital, services, and goods together in a way that drives economic growth, innovation, job creation, and higher standards of living (Black and Henderson 1999; Rosenthal and Strange 2004; Bettencourt et al 2007; Glaeser 2011). In 2013, around just 770 of the world's biggest cities accounted for nearly 60 percent of global economic output while representing only about 35 percent of the world's population and 28 percent of its workforce.[1]

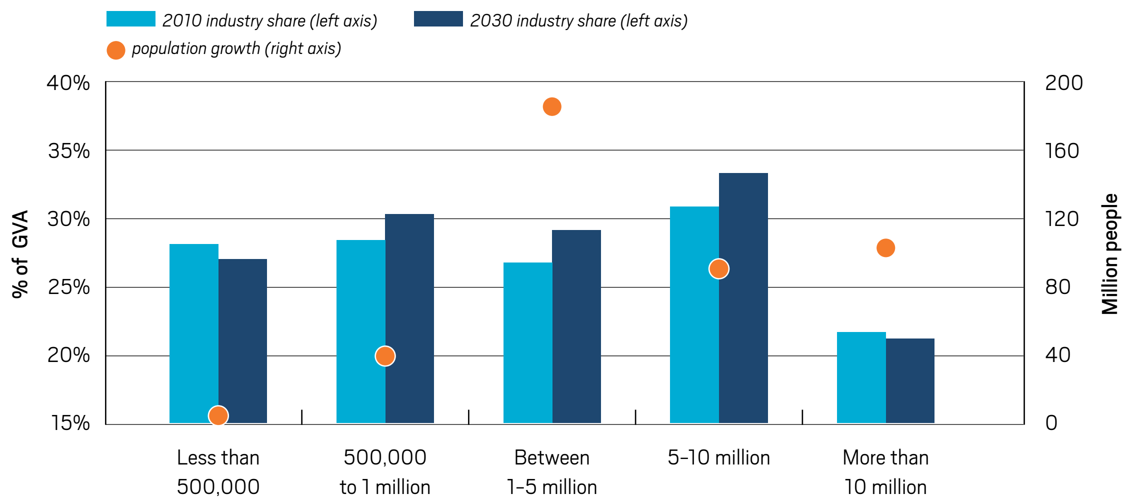
The vibrancy of cities goes hand in hand with their hunger for energy. Cities are responsible for about three-quarters of global energy use and are the source of most of the carbon emitted into the atmosphere from burning fossil fuels (Seto et al 2014).

Industry has played a notable role in the rise of cities, drawing migrants into urban areas with jobs and boosting the productivity of capital and labor (Michaels, Rauch, and Redding 2012). Urban areas, in turn, have provided a fertile environment for industry to grow, offering economies of scale, sizeable labor pools, networks for sharing information, and access to a diverse array of input and service suppliers (Annez and Buckley 2008). The productivity advantages of urban areas for industry have been observed in both developing and developed countries.

The dynamics of the two-way relationship between cities and industry will largely persist over the coming decades. Despite a structural adjustment in the urban economy toward services, industry will continue to have a sizeable footprint. According to projections by Oxford Economics for the 770 big cities mentioned above, the share of industry in value-added is projected to rise slightly from 27 percent in 2010 to 29 percent in 2030. Most of this growth will be seen in medium to large-sized cities with between 1 million and 10 million people (figure 1). These cities will also account for the majority of population increase in urban areas. Industry will continue to employ about one-quarter of urban dwellers, or about 1.1 billion people.

1 Analysis by the authors using city-level estimates of gross value added and population from Oxford Economics and national-level data on labor force size and activity from the ILO, ILOSTAT.

FIGURE 1: Industry will have a greater presence in the fastest growing subset of cities, by population



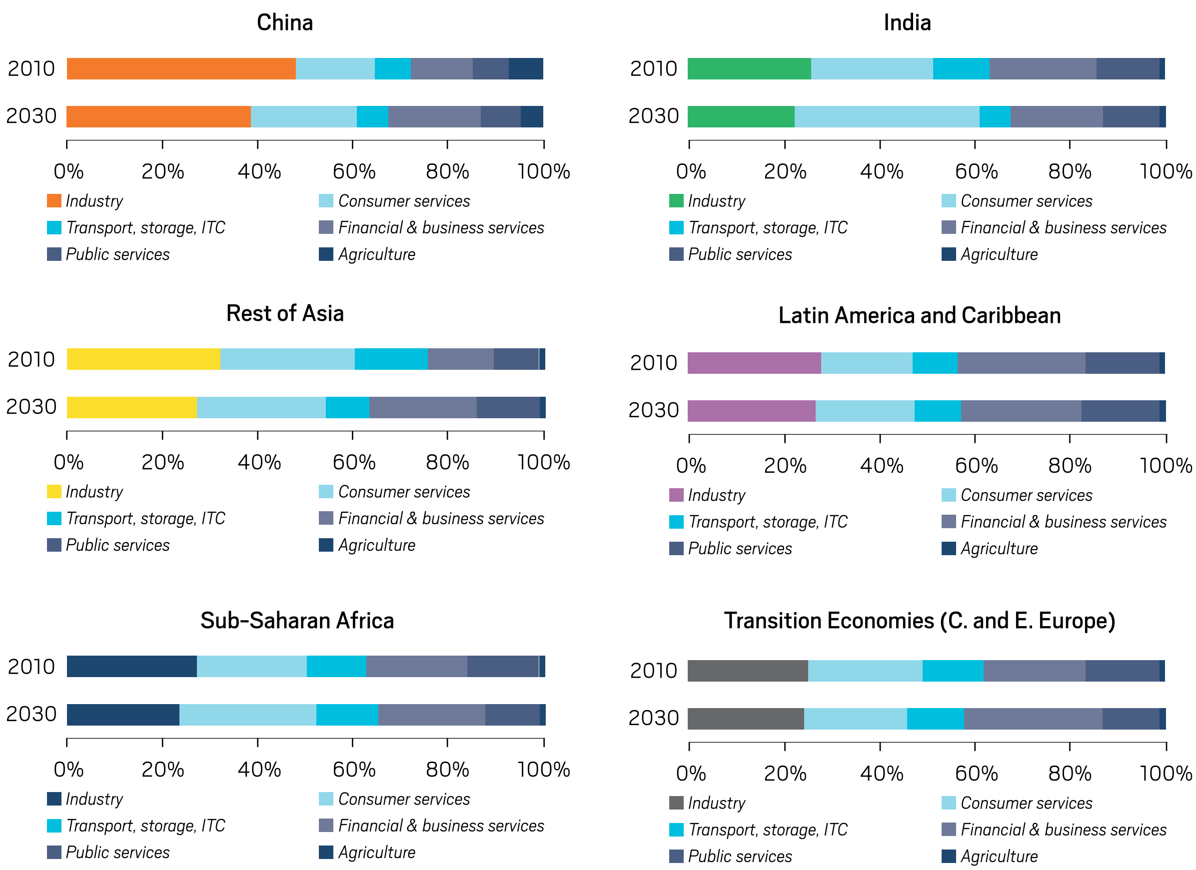
Source: Estimates for 772 cities; analysis by the authors using data from Oxford Economics.

One of the most striking trends in the projections for the upcoming decades is the continuing predominance of industry in Chinese cities (figure 2). The forces behind this trend warrant a closer look. China's economic growth over the past decade has been fueled by an incredible build-up of fixed assets. Outlays on new factories, production line machinery, residences, commercial buildings, roads, railways, and other physical assets in China comprised about half of GDP in 2011 (World Bank World Development Indicators). With such massive investment in physical capital, demand for building materials such as steel, concrete, aluminum, and glass, along with other manufactured inputs, has bolstered the rapid growth of heavy industry and had a dramatic effect on energy demand. Since 2000, energy demand by four of the most-energy intensive subsectors (ferrous metals, non-ferrous metals, non-metallic minerals, and chemicals) has increased by nearly a factor of 3. These sectors represent over half of industrial energy demand and 40 percent of the nation's total energy demand (China NBS 2013a, 2013b).

Over the next 10 to 20 years, China's economy will gradually slow, with annual growth in fixed assets expected to be about 60 percent of what it was between 2000 and 2010 (Liu, Chen, and He 2013). The effects of this slowdown will hit hardest in the heavy industrial sectors, and with less robust demand for building materials and other industrial commodities, energy demand by heavy industry is expected to plateau by around 2020. However, while heavy industry's percent share in total energy demand and economic output will diminish, in absolute terms, it will continue to be the largest end-user of energy in China's economy (Fridley et al 2012). The slowdown of heavy industry will require another set of priorities – responsible downsizing and dealing with legacy issues for old, environmentally-hazardous heavy industrial plants in urban areas, abandoned as part of this restructuring in favor of higher value industry or services.

The lasting footprint of industry in cities has important implications for global energy use. Between 2010 and 2030, final industrial energy demand is projected to increase globally by anywhere from 1.6 billion tons of oil equivalent (Btoe) per year to 4.3 Btoe per year in a baseline scenario (figure 3). By comparison, total final energy consumption for the United States in 2010 was 1.5 Btoe (IEA World Energy Statistics). Industrial energy demand will remain relatively flat in OECD countries and in the transition economies of Central and Eastern Europe, but it will increase dramatically in the emerging economies of Asia, including in China and India, and to a lesser extent in the Middle East and Africa (figure 3). Industry will continue to be dominant user of dirty fuels such as coal (IEA 2014b).

FIGURE 2: While cities around the world will shift toward services, industry will remain an important sector of the urban economy



Source: Estimates for 772 cities; analysis by the authors using data from Oxford Economics.

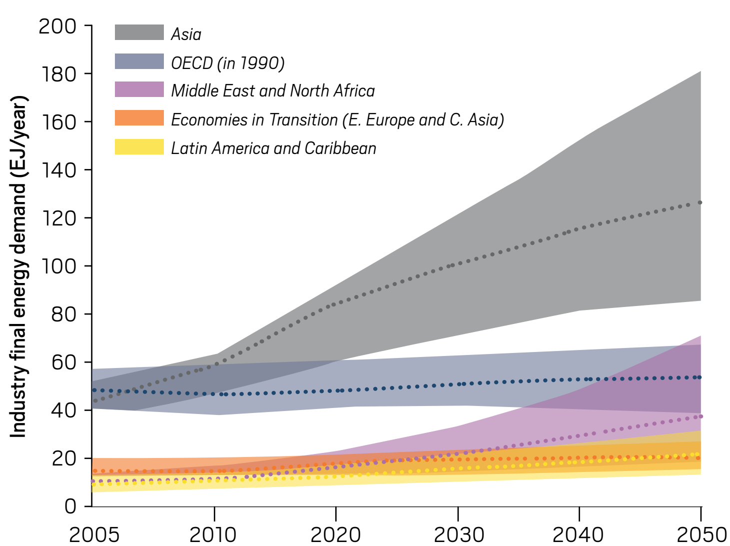
With a continued reliance on fossil fuels, particularly coal, higher energy use in cities has translated into increased emissions of both local and global air pollutants. While compact, connected, and well-managed cities have the potential to be highly efficient and reduce their environmental footprint (Glaeser and Kahn 2010; Floater and Rode et al 2014a), the opposite has proven true in many rapidly urbanizing areas, as cities have required much more energy, electricity, and water and emitted more tons of carbon per capita than rural areas (UNEP 2011; Grubler et al 2012). Many factors have contributed to the larger environmental impact of cities, including unchecked sprawl, greater demand for energy services, such as heating in buildings, and dependency on the use of private cars. The diverse challenges faced by cities and the variation in urban emissions sources are reflected in figure 4, which shows the energy-related GHG emissions profiles of cities around the world.

Together, the 86 cities included in figure 4 emit around 2.08 billion tons of CO_2 equivalent each year, of which industrial end users are responsible for 940 million tons. The Chinese cities have the most dominant industrial sectors (figure 5), with per capita emissions higher than many cities in the OECD, due in part to the higher carbon intensity of their electricity supply. Urban industry is also the largest source of energy-related carbon emissions for cities in other East Asian countries and in South Africa (figure 5). Industry plays a smaller role in the GHG profiles of the North American, European, and Latin American cities, accounting for between 11 percent and 14 percent of total emissions.

Given the dominant place of industry in the energy and GHG emission profiles of many Asian cities, particularly in China, it is no surprise that industry also contributes to the high levels of local air pollution in the region (figure 6). According to the Global Burden of Disease study, 2.2 million people in East and South Asian countries died prematurely in 2010 due to poor ambient air quality (IHME). In the northern region of Beijing, Tianjin, and Hebei in China, annual exposure to $PM_{2.5}$ averaged 108 micrograms per cubic meter (μg/m^3) in 2013 — more than 10 times the guideline value recommended by the WHO (Greenpeace 2014).[2] Researchers estimate that steel, cement, and brick producers account for 49 percent of $PM_{2.5}$ emissions in the region. Industrial electricity use is indirectly responsible for another 6 percent of $PM_{2.5}$ emissions produced by coal–burning power plants (Guan and Liu 2013). Emissions come mainly from burning coal in power plants, large boilers and heat plants, and from industrial processes that discharge large amounts of dust (e.g., smelting ferrous metals) (World Bank–MEP 2012; World Bank–DRC 2014). Large industrial facilities are not the only culprits. In Dhaka, for example, around 20 percent of $PM_{2.5}$ concentrations in the metro area are produced by the thousand or so brick kilns that ring the city (Rahman et al 2011; Begum et al 2013). Most of the brick makers around Dhaka are small, individual operators who fire their kilns by burning coal or agricultural residues during the harvest season. Emissions from these thousand or so brick kilns kill up to 500 people and result in 1,700 emergency room visits each year (Guttikunda and Khaliquzzaman 2013). Other industrial sources of $PM_{2.5}$ pollution in Dhaka include lead smelters and galvanizing factories (Begum et al 2013).

2 Average annual exposure to $PM_{2.5}$ is calculated as a population-weighted average of concentrations in 13 cities in the Jing-Jin-Ji region where $PM_{2.5}$ was monitored in 2013.

FIGURE 3: Industrial energy use will increase in the coming decades, particularly in Asia



Notes: colored bands represent the 5th to 95th percentiles of more than 100 baseline scenarios included in IPCC's Fifth Assessment Report, with the dotted line showing the median scenario for the region.

Source: data from IPCC WGIII (2014), obtained from the International Institute for Applied Systems Analysis database.

FIGURE 4: Greenhouse gas emission profiles of cities are varied but confirm the importance of urban industry as an end user of energy and an emitter of carbon in fast-growing regions

Note: The emissions profiles of nine Latin American cities, though surveyed, are not presented here. Emissions inventories surveyed generally include direct (Scope 1) and indirect (Scope 2) emissions, though specific methodologies vary from city to city.

Sources: data from carbon*n*, Wang et al (2012), Zhu et al (2012), Ramachandra et al (2014), and Ostojic et al (2013).

FIGURE 5: The per capita emissions of cities in developing countries with dominant industrial sectors are approaching or exceeding those of cities in the OECD countries

Sources: data from carbon*n*, Wang et al (2012), Zhu et al (2012), Ramachandra et al (2014), and World Bank (2013).

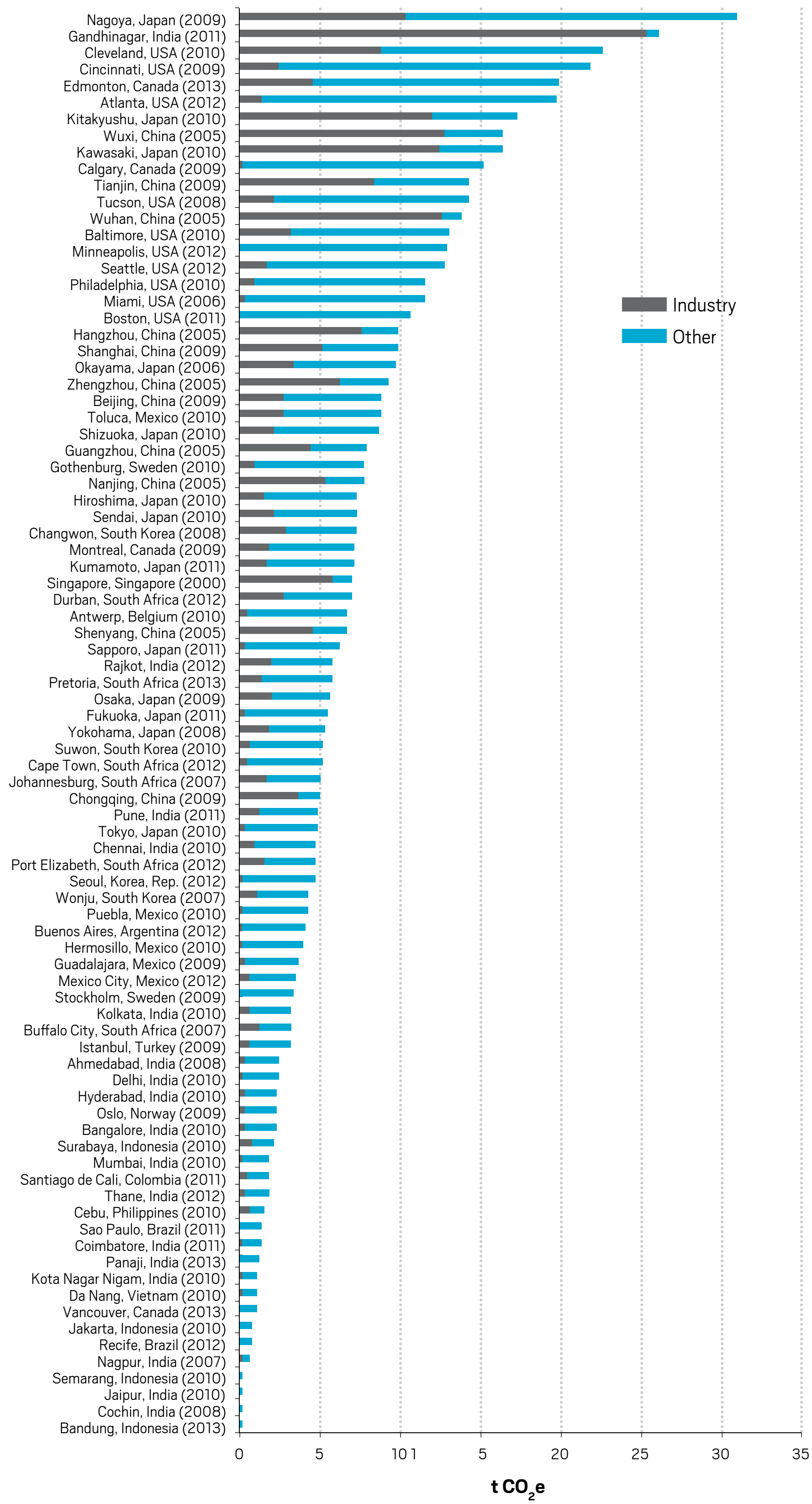
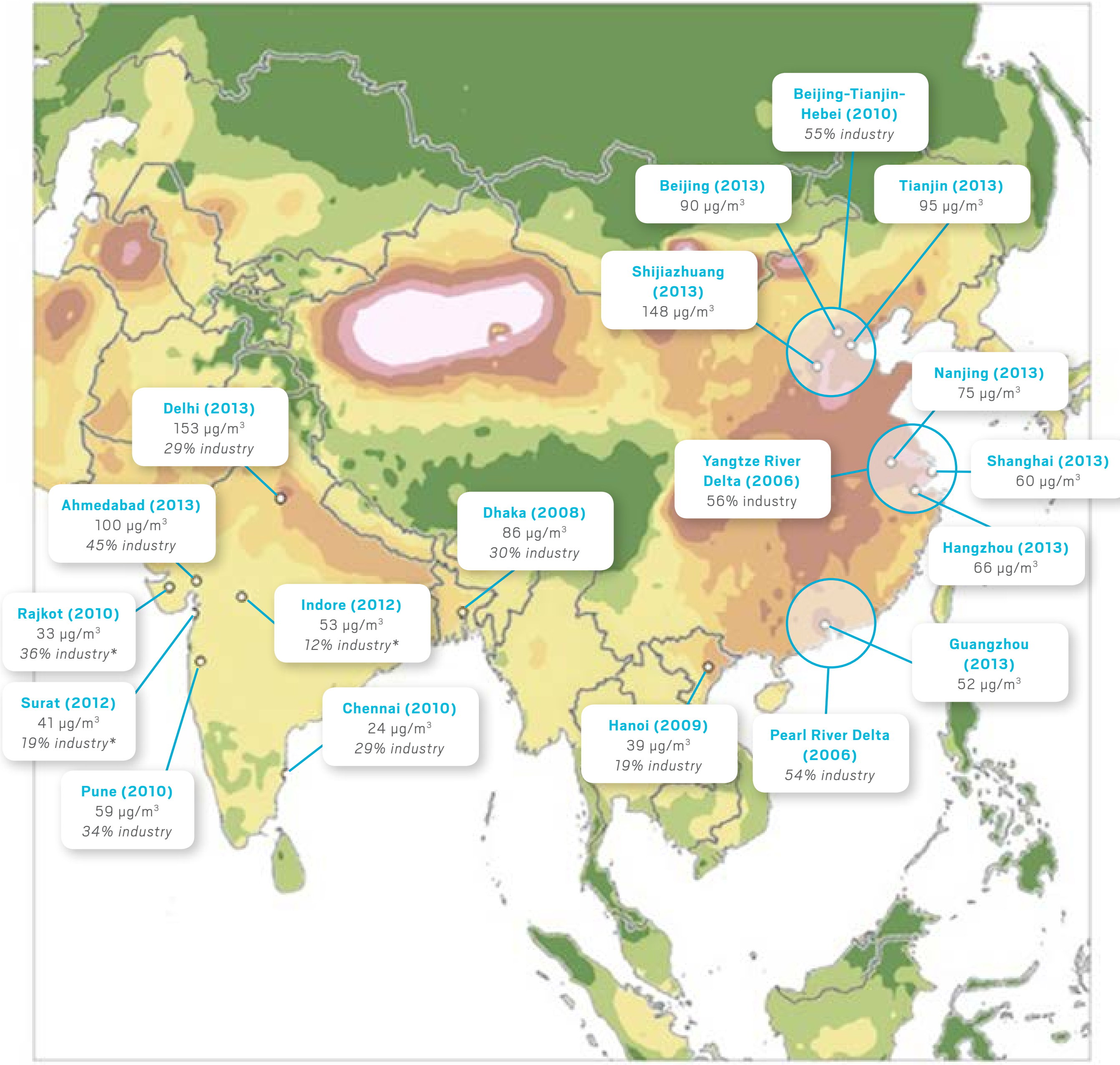


FIGURE 6: $PM_{2.5}$ pollution in Asian cities, and industry's contribution to emissions



Notes: Base map shows estimates of $PM_{2.5}$ concentrations in 2010, as found by the Global Burden of Disease study (Brauer et al 2012). Concentrations for individual cities are ground-monitored and vary by year. Percentages are industrial share of $PM_{2.5}$ emissions and may not correspond with the year of concentrations. Asterisks (*) indicate the industry share of PM_{10}, not $PM_{2.5}$.

Source: authors used data from Zheng et al (2009); Guttikunda and Jawahar (2012); Brauer et al (2012); Begum et al (2013); Fu et al (2013); Guan and Liu (2013); Guttikunda et al (2013 and 2014).

To mitigate pollution, cities have typically sought to move heavy industry away from the urban core. This migration of industry to peri-urban areas has had positive effects but has also come at a social cost. In many developing-country cities, stringent limits on density and an inelastic supply of housing have boosted housing prices in city centers and have pushed the working class out to the suburbs (Hoornweg and Freire 2013). The coincident movement of industry and the working class to the urban margins is evident in India, for example, where manufacturing jobs in rural areas directly adjacent to large metro areas grew by 45 percent between 1998 and 2005 — far faster than the rate inside the cities (World Bank 2013).

As the cities continue to expand outward and sprawl ensues, more and more people settle in close proximity to industrial energy users and emissions sources. In the rapidly urbanizing provinces of eastern China, studies have shown that suburban townships inhabited by large numbers of migrant workers suffer disproportionately high exposure to industrial sources of pollution such as factories, waste treatment facilities, and power plants (Ma 2010; Schoolman and Ma 2012). The impact of industrial pollution on the urban poor is not unique to developing countries and has been well-documented in US cities, where industrial facilities releasing toxics into the air, soil, and water tend to be concentrated in areas with higher numbers of low-income and minority residents.[3]

3 See Bullard (1993); Daniels and Friedman (1999); Mennis (2005), and Abel (2008) for examples. Note that while the case of US cities and developing countries are similar in terms of the higher burden imposed on more vulnerable segments of the urban population, the dynamics of this relationship depend on differing political, social, and economic forces and the individual circumstances of cities.

3 The benefits of industrial energy efficiency for cities

Putting greater focus on industrial energy efficiency in planning and managing cities can benefit both industries and cities — improving public health and reducing social, economic, and environmental costs. Globally, the International Energy Agency (IEA) estimates that the industrial sector has the potential to reduce energy use by 7.4 Btoe between 2012 and 2035 by making investments with viably short payback periods (IEA 2012).[4] To put that number in perspective, these energy savings would provide an equivalent of more than four years of total energy use by the EU. The vast majority of energy savings comes from non-OECD countries where cities are expected to grow fastest. Seizing these opportunities for efficiency would generate an additional $18 trillion in global economic output, offering GDP gains of 2-3 percent per year for China and India. Without supportive policies, however, more than 60 percent of the economically-viable energy savings in industry would go unrealized.

Continued improvements in energy efficiency can help industries become more competitive by reducing operating costs, generating additional value, and mitigating risks (Cooremans 2012; IEA 2014b). Investments in energy efficiency may generate additional value by boosting productive capacity, improving product quality, or enhancing the value of the company's brand among consumers. More efficient use of energy mitigates risk by reducing exposure to volatile input prices, particularly for the heavy sectors. Industries in cities come in many shapes and sizes and span a broad array of sectors, so the relative importance of different benefits to competitiveness varies from case to case. In some cases, direct cost savings on energy may be small compared to other benefits (IEA 2014a). One review of energy efficiency upgrades by manufacturers of building materials, iron and steel, chemicals, and food in OECD countries found that annual productivity gains by companies were 1.2 times larger than the value of energy savings alone. By including the broader economic benefits to companies, the average payback period for projects falls from 4.2 years to 1.9 years (Worrell et al 2003).

The potential economic benefits of industry efficiency to the wider urban economy include job creation, reduced infrastructure costs, and avoided costs from air pollution. The co-benefits for air quality are especially pronounced in urban areas where industry relies primarily on dirty fuels such as coal. For example, in China, the economic cost of death, illness, and disability associated with particulate matter pollution in cities in 2005 was nearly US$ 188.2 billion, or 6 percent of GDP (Matus et al 2012).[5] Of this, heavy manufacturing in and around urban areas was responsible for US$ 121.9 billion in annual damages.[6] By 2030, progressive improvements in end-use energy efficiency for industrial facilities, buildings, and road transport could reduce PM pollution costs by around US$ 33.6 billion (He et al 2010). But efficiency improvements will need to be coordinated with end-of-pipe controls, phasing out old coal-fired power plants, switching district heating from coal to natural gas, tougher vehicle emission standards, and other pollution abatement measures. Together, these abatement measures would reduce the cost of PM pollution by another US$ 79.3 billion (Ibid).

Cost-effective efficiency improvements by industry will also enable cities to reduce their emissions of greenhouse gases. A bottom-up analysis of low-carbon investments in a diverse group of six cities in India, Malaysia, Indonesia, Peru, and the United Kingdom identified cost-saving solutions that could help each city reduce its carbon emissions by 14 percent to 24 percent in 2025 (Gouldson et al 2014). Payback periods for the suite of investments in these cities ranged from less than one year to around four years. While the size, economic structure, and income level of these cities run the gamut, industrial energy efficiency improvements offered them significant carbon and cost savings (figure 7).

Numerous studies at the national or regional level have supported the claim that improvements in energy efficiency can spur job growth. The Rhodium Group estimated that doubling

4 In the IEA analysis, energy efficiency investments in industry that are economically viable are defined as those with an average payback period of five years for OECD countries and three years for non-OECD countries. Payback periods are calculated on the basis of direct energy savings over asset lifetimes and do not include broader operational and productivity benefits. The industrial sectors analyzed include the most energy-intensive sectors (iron and steel, chemicals, cement, pulp and paper) as well as other industries (IEA 2012).

5 All costs are adjusted to 2010 US dollars for comparison's sake.

6 Analysis by the authors, assuming the share of heavy manufacturing in mortality and morbidity from PM_{10} pollution in urban areas as estimated by Fang et al (2011) for 2007. Damages from electricity generation in urban areas are allocated to industry on the basis of industry's share in electricity consumption (about 70%).

the energy productivity of the US economy by 2030 would generate 530,000 new jobs in manufacturing — net of job losses linked to declining revenue in extractive industries and other sectors (Rhodium Group and Alliance to Save Energy 2013). In Europe, every EUR 1 million invested in energy efficiency has been estimated to create 11-12 new jobs and boost GDP by EUR 1.8 million (IEA 2014a). At the local level, the net effects of industrial energy efficiency programs are more difficult to judge. Whether more jobs will be created or lost depends on the individual circumstances of the city's economy and may be influenced by policy choices made outside the city's control. In China, for example, as many as 400,000 workers lost their jobs in the iron and steel sector when the central government moved to shut down small and outdated facilities as part of a massive campaign during the 11th Five Year Plan (2006-2010) (IUE-CASS 2010). Additional jobs were lost due to closures in the cement sector. Cities such as Zibo in Shandong province were particularly hard hit and spent millions from local coffers in providing resettlement assistance to displaced workers and compensating factory owners (Li et al 2009). Other cities have fared better. In the United States, the car company Nissan shaved its energy consumption by 30 percent and reduced costs by US$ 11.5 million after implementing an energy management system, allowing it to expand its power train plant in Decherd, Tennessee. In another town in Tennessee, Smyrna, Nissan received a loan from the US Department of Energy to retrofit its plant and launch production of a zero-emission electric vehicle, which will support 1,300 jobs (Bell 2011). The contrasting experiences of Decherd, Smyrna, and Zibo highlight the importance of policy design in weighing job growth with energy savings.

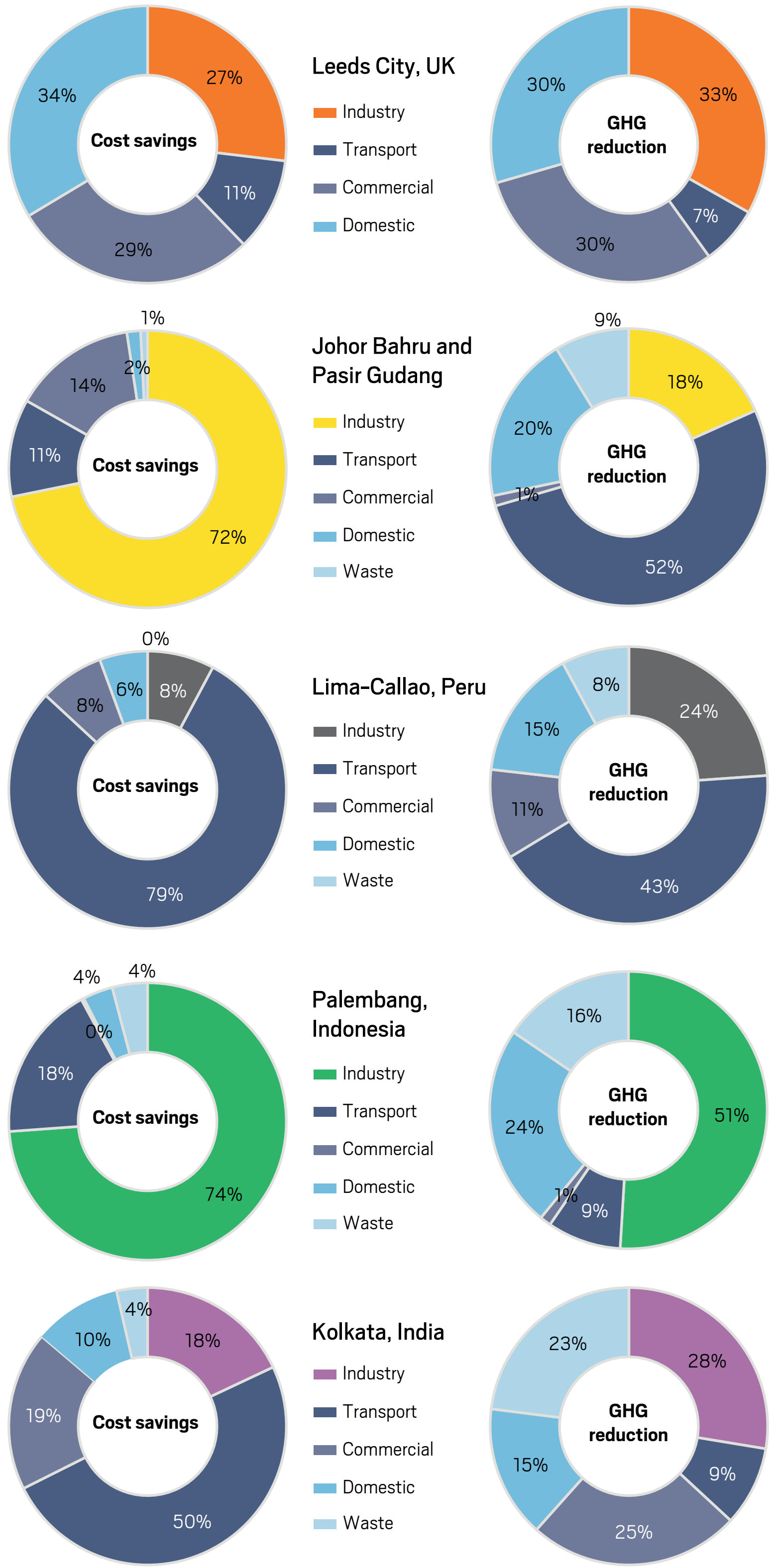
Smart policies and integrating industrial energy efficiency with other areas of urban planning will also be instrumental in reducing infrastructure costs and bridging investment gaps. With business-as-usual development in many rapidly-expanding cities pushing industry out to the margins, the unit costs of providing basic services to these areas are amplified. Municipal governments tend to only plan the "official city" and to ignore areas outside their administrative boundaries. The actual growth of the larger metro area is ignored or not regulated until later, after the pressure on infrastructure services in the city reaches a critical point (Hoornweg and Freire 2013). As a consequence of fragmented planning and lack of allocated resources, service reliability in the urban fringe suffers. Energy efficiency can help alleviate the strain placed on service supply systems, especially with shortfalls in investment needed for new capacity. In South Africa, for instance, peak electricity demand is expected to nearly double by 2025. To meet this demand, Eskom, the utility company, is currently building two new coal-fired power plants, but with rising concerns over climate change, the company is facing pressure to not build any more (South Africa NPC 2012). Pricing adjustments, public financing, and other reforms are needed to overcome the challenges faced in South Africa, but cutting demand through end-use efficiency investments will certainly help, especially in metro areas such as Durban, where heavy industry is the largest consumer of electricity (Thambiran and Diab 2011).

Finally, resource-efficient cities may also be more resilient to extreme weather and climate change. After Hurricane Sandy, schools, hospitals, housing complexes and other facilities with combined heat and power systems (CHP) were able to stay warm and keep the lights on despite large-scale disruptions to the central electricity grid.[7] CHP recovers waste heat from thermal power production for use in space heating and cooling, delivering significant efficiency benefits. President Obama has issued an executive order for federal agencies to provide incentives and support to manufacturers in installing 40 gigawatts of new CHP capacity by 2020, potentially saving more than $100 million to the economy and generating as much electricity as 80 coal-fired power plants could over their entire lifetime.[8]

7 www.ase.org/resources/chp-kept-schools-hospitals-running-amid-hurricane-sandy

8 www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency; www.ase.org/resources/obamas-executive-order-invests-industrial-energy-efficiency; www.greentechmedia.com/articles/read/bending-the-curve-on-industrial-energy-efficiency

FIGURE 7: In five of six cities surveyed, industry offers either the most cost-effective mitigation options or the largest margin of GHG emissions reduction potential in 2025



Source: Gouldson et al (2014).

4 What cities can do to boost low carbon industry

In response to the enormous challenge posed by growing urban energy demand, a number of authors have pointed to the need for sustainable, green cities to be more compact, better connected, and better managed (Grubler et al 2012; Floater and Rode et al 2014; GCEC 2014). More compact cities are better able to reap the economic benefits of bringing people, ideas, information, and activities together while also reducing overall energy requirements, particularly for road transport. Better connected cities can provide basic infrastructure services at a lower cost and with greater reliability while also recycling waste streams. And better managed cities have the technical, institutional, and financial capacity to control the social and environmental costs of urban density, including traffic congestion and pollution.

The push for more compact, better connected, and better managed cities has made industrial energy efficiency all the more important for the sustainability agenda of many of the world's cities. Industrial energy efficiency does not begin and end at the factory door, and neither do the effects of industrial energy use. Realizing the economic potential for reducing industrial energy use and lightening the environmental footprint of cities will involve enterprises, local city governments, financial institutions, technical service providers, and higher levels of government alike. Thankfully, much of the know-how is already in place to stimulate deeper gains in efficiency.[9]

Proven technologies are available that can reduce energy use in manufacturing facilities while also cutting the flow of waste and pollution in urban areas. The high density of urban energy demand and the proximity of industry to other end users in some cities, for example, make it possible to recycle lower-grade heat and other waste energy from industrial operations in the form of clean district heating and cooling services (Grubler et al 2012). Cities in Sweden offer compelling examples of the possibilities. In the northern city of Lulea, residual gases produced by a steel mill are used to fire a nearby CHP plant, satisfying the heating needs for most of the buildings in the city in addition to providing sufficient electricity to power the mill's operations. Consumers in Lulea enjoy some of the lowest tariffs for district heating in the entire country (Grip et al 2010). In Gothenburg, oil refineries provide the base-load for the municipally-owned district heating system (Holmgren 2006), serving the second largest municipality in the country. Opportunities for waste heat recovery within industrial plants are also substantial. The US EPA estimates that improved waste heat recovery (WHR) could reduce energy use in industrial facilities by 10-50 percent (US EPA 1998). In the cement sector, the IFC and IIP estimate that the worldwide market potential for WHR is around US$ 5 billion, representing about 1.6 GW to 2.9 GW in electricity generating capacity (IFC-IIP 2014) — the equivalent of the Hoover Dam in the United States.

The potential for reducing waste while saving energy works in other ways too. With many kinds of industrial producers clustered in cities, manufacturers can save energy by reutilizing municipal waste or byproducts from other industrial operations. As a case in point, in the European Union, about 17 percent of the thermal energy used by cement producers comes from incinerating municipal solid waste (MSW) and sewage sludge in kilns (with appropriate emissions controls for dioxins, furans, and other toxics) (IPCC 2014: 755). In India, less than 1 percent of cement manufacturers use alternative fuels and raw materials (AFR) at present (IIP 2013b), but the Cement Manufacturers' Association of India plans to raise this figure to 15 percent by 2020. Achieving this target will involve substituting coal for such fuels as MSW and reducing the amount of clinker in finished cement. If this target is met, Indian cement-makers would save nearly US$ 2.5 billion in cumulative fuel costs and reduce their CO_2 emissions by 16.2 million tons (IIP 2013b).

The role of city governments in encouraging energy savings by industry will vary depending on their individual circumstances (Ostojic et al 2013; Floater and Rode et al 2014a). Individual cities generally have relatively little influence over important aspects of upstream energy supply such as the price or fuel mix of electricity from the regional grid.[10] They also have relatively little control over subsidies, taxes, and regulations for the energy sector, meaning that higher levels of government will need to provide appropriate and sustained support for

9 www.greentechmedia.com/articles/read/bending-the-curve-on-industrial-energy-efficiency

10 That said, larger cities may be able to exercise more influence over power suppliers given their sizeable market position and some cities, such as New York, have mandated that a certain share of electricity be generated locally.

industrial energy efficiency in these areas. Cities can usually control infrastructure contained within their borders, including district heating networks and waste treatment facilities; and they exercise important influence over certain aspects of energy demand — for example by installing electricity meters, reducing leakage rates from outdated distribution networks for piped gas and heat, or by reducing private vehicle use in scaling up public transport. City policies have had both positive and negative effects on industry energy use. Land-use planning and zoning requirements have exerted a strong influence over the location of industrial energy users within or outside the metro area, and local bans on the use of dirty fuels in some cities have led heavy industries to relocate in suburbs. Cities have also sought to attract industries through such incentives as cheap land, discounted taxes, loans, paid-for expansions in energy supply infrastructure to the factory gate, or rebates on utility bills.

For the majority of cities, the top priority for managing energy use by industry will be to start with the basics by laying the technical, institutional, and financial groundwork for progressively more ambitious action.[11] According to the World Bank, less than 20 percent of the world's largest cities have the analytics needed for low-carbon planning.[12] In China, city governments have struggled to keep up with their rapidly-increasing responsibility for providing day-to-day oversight and enforcement in the country's massive campaign for industrial energy efficiency (Taylor et al 2010). The governments in small municipalities may only have one or two people assigned to monitor equipment and production standards, meet with local plant managers, conduct on-site inspections, and evaluate the accuracy and technical rigor of energy use reports submitted by firms (see Kostka and Hobbs 2012). For these cities — and many others — the first step toward effective management of energy use will be investing in monitoring and reporting systems, and performing emissions inventories for GHG and local pollutants (see Ostojic et al 2013). Financial and technical support from higher levels of government as well as international networks and organizations will play a vital role in this effort.

Cities with greater technical capacity may help promote the widespread adoption of energy management systems (EnMS) in industry. EnMS provides industries with a set of practices and procedures for identifying and implementing energy efficiency improvements. For leading companies such as Dow Chemical, practicing good EnMS has been fundamental to making continuous improvements in energy efficiency (Goldberg, Reinaud, and Taylor 2011), allowing them to realize energy savings of up to 10-30 percent of total energy use across facilities. Voluntary uptake of EnMS has become widespread in Europe, with EnMS-certified industries representing 50-60 percent of total industrial energy use in Denmark and Ireland and 50 percent of total electricity use in Sweden, for example (Ibid). EnMS has become mandatory for more than 10,000 of the largest industrial energy consumers in China, where local governments are now being held accountable for ensuring that industries in their jurisdiction have implemented EnMS. While such requirements create the risk of perfunctory, compliance-driven adoption by industries, local city governments can play a positive role in encouraging EnMS as a way for industries to save costs and enhance their bottom-lines. These governments can act as informational clearinghouses in providing training and popularizing successful case studies with local industries. They may also help connect local industries to a network of qualified professional service providers (IIP 2013a).

Building strong institutional arrangements for managing energy use can be a challenge even for technically-sophisticated cities. But with leadership and political commitment, these challenges may be overcome. Traditional approaches to urban planning treat infrastructure water supply, wastewater treatment, solid waste management, electricity, and heating separately, but planning for efficient cities requires that these services be coordinated so as to reduce the overall energy demand of the urban system. This means integrating the authority of different agencies in the city responsible for operating and maintaining infrastructure and services, an effort that would ideally be led by the mayor's office or a city-wide task force, such as PlaNYC in New York City (see Zhou and Williams 2013; World Bank-DRC 2014).

11 Some cities, such as Chicago, have already set out comprehensive plans for reining in energy use and GHG emissions and established their own investment platforms to finance energy efficiency and other green projects.
12 www.worldbank.org/en/news/press-release/2013/09/25/world-bank-initiative-planning-finance-challenges-300-low-carbon-livable-cities

Cities with transparent accounting systems, integrated authority, and strong leadership will be well-positioned to mobilize greater resources for energy efficiency (Floater and Rode et al 2014b; GCEC 2014). The fiscal powers of cities have traditionally extended primarily to land and property taxes, which represent about 70 percent of the tax revenues collected in US cities (Ibid). Other important sources of revenue may be off-budget, such as fees from converting and leasing land, but these have contributed to sprawl and less-efficient urban forms. The World Bank estimates that only a small percentage of the world's largest cities are deemed creditworthy, limiting their access to financial markets domestically and abroad.[13] While raising a city's credit rating is a multi-year effort, it can have a substantial payback in allowing cities to leverage more finance from the private sector for low-carbon investments, including in energy efficiency (Ibid).

13 www.worldbank.org/en/news/feature/2013/10/24/financing-sustainable-cities-africa-creditworthy

5 Conclusion

The world's cities are as diverse as the challenges that face them, but the importance of improving energy efficiency in industry is common to many.

Over the next few decades, industry will remain a vital feature of the global urban economy, providing more than a billion jobs and generating nearly 30 percent of economic output. As industrial energy requirements in rapidly-developing regions, such as East and South Asia, will continue to rise, any strategy to reduce fossil energy use and greenhouse gas emissions in a timeframe that is meaningful to avoiding dangerous climate change will have to consider options for deepening energy efficiency in urban industry. Many of these options are cost-effective and have short payback periods.

Achieving more of the full potential for cost-effective energy savings in industry will deliver benefits to the wider city economy. Reduced air pollution, which causes hundreds of billions of dollars in damages to public health each year, is just one of the benefits. Other potential benefits might include reduced infrastructure costs and job creation.

Capturing these benefits will require smart policy design and planning at the city level as well as adequate support from higher levels of government. Local governments should focus first on laying the technical, institutional, and financial groundwork that will enable them to progressively capture more of the economic potential that exists for energy efficiency in rapidly-growing urban areas. Subsequent measures may include land-use planning and zoning requirements to exert a strong influence over the location of industrial energy users within or outside the metro area; clustering of industries in industrial parks to make it possible to recycle lower-grade heat and other waste energy, and reutilizing municipal waste or byproducts from other industrial operations; and building the technical capacity to help promote the widespread adoption of energy management systems (EnMS) in industry. Cities with transparent accounting systems, integrated authority, and strong leadership will be well-positioned to mobilize greater resources for cleaner industry, thus enabling their own transformation to greener cities.

6 References

Abel, T.D. 2008. "Skewed Riskscapes and Environmental Injustice: A Case Study of Metropolitan St. Louis." *Environmental Management* 42: 232-248.

Annez, P.C. and R. Buckley. 2008. "Urbanization and growth: Setting the context" in *Urbanization and Growth*, edited by M. Spence, P.C. Annez, and R. Buckley. Washington, DC: Commission on Growth and Development, World Bank.

B.A. Begum, P. Hopke, and A. Markwitz. 2013. "Air Pollution by Fine Particulate Matter in Bangladesh." *Atmospheric Pollution Research* 4: 75-86.

Bell, C.J. 2011. "Understanding the True Benefits of Both Energy Efficiency and Job Creation." Community Development Investment Review, Federal Reserve Bank of San Francisco.

Bettencourt, L.M.A., J. Lobo, D. Helbing, C. Kühnert, and G.B. West. 2007. "Growth, Innovation, Scaling, and the Pace of Life in Cities." *Proceedings of the National Academy of Sciences* 104: 7301-7306.

Black, D. and J.V. Henderson. 1999. "A Theory of Urban Growth." *Journal of Political Economy* 107: 252-284.

Brauer, M., M. Amman, R.T. Burnett, A. Cohen, F. Dentener, M. Ezzati, S.B. Henderson, M. Krzyzanowski, R.V. Martin, R. Van Dingenen, A. van Donkelaar, and G.D. Thurston. 2012. "Exposure Assessment for Estimation of the Global Burden of Disease Attributable to Outdoor Air Pollution." *Environmental Science & Technology* 46, doi: 10.1021/es2025752.

Bullard, R.D. 1993. "Race and Environmental Justice in the United States." Yale J. Int'l L. 18: 319-336.

carbon*n* Climate Registry. http://carbonn.org/.

China DRC (Development Research Center, State Council, PRC). Unpublished.

China NBS (National Bureau of Statistics, PRC). 2013a. China Statistical Yearbook. Beijing: China Statistics Press.

China NBS. 2013b. China Statistical Yearbook of Energy. Beijing: China Statistics Press.

Cooresmans, C. 2012. "Investment in Energy Efficiency: Do the Characteristics of Investments Matter?" *Energy Efficiency* 5: 497-518.

Daniels, G. and S. Friedman. 1999. "Spatial Inequality and the Distribution of Industrial Toxic Releases: Evidence from the 1990 TRI." *Social Science Quarterly* 80: 244-261.

Fang, B., Liu C.F., Zou L.L., and Wei Y.M. 2012. "The Assessment of Health Impact Caused by Energy Use in Urban Areas in China: An Intake Fraction-Based Analysis." *Natural Hazards* 62: 101-114.

Fischedick M., J. Roy, A. Abdel-Aziz, A. Acquaye, J. M. Allwood, J.-P. Ceron, Y. Geng, H. Kheshgi, A. Lanza, D. Perczyk, L. Price, E. Santalla, C. Sheinbaum, and K. Tanaka. 2014. "Industry" in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx. Cambridge, United Kingdom and New York, NY: Cambridge University Press.

Floater, G. and P. Rode, et al. 2014a. "Cities and the New Economy: The Transformative Role of Global Urban Growth." The New Climate Economy Report background paper, Global Commission on the Economy and Climate. http://www.newclimateeconomy.net.

Floater, G. and P. Rode. 2014b. "Steering Urban Growth: Governance, Policy, and Finance." The New Climate Economy Report background paper, Global Commission on the Economy and Climate. http://www.newclimateeconomy.net.

Fridley, David, Nina Zheng, Zhou Nan, Ke Jing, Ali Hasanbeigi, Bill Morrow, and Lynn Price. 2012. "China Energy and Emissions Paths to 2030 (2nd Edition)." Report LBNL-4866E, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California, United States.

Fu, X., Wang S.X., Zhao B., Xing J., Cheng Z., Liu H., and Hao J.M. 2013. "Emission Inventory of Primary Pollutants and Chemical Speciation in 2010 for the Yangtze River Delta Region, China." *Atmospheric Environment* 70: 39-50.

Glaeser, E. 2011. *The Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier*. London: Pan Macmillan.

Glaeser, E. and M.E. Kahn. 2010. "The Greenness of Cities: Carbon Dioxide Emissions and Urban Development." *Journal of Urban Economics* 67: 404-418.

GCEC (Global Commission on the Economy and Climate). 2014. *Better Growth Better Climate: The New Climate Economy Report, The Global Report*. World Resources Institute, Washington, DC.

Goldberg, A., J. Reinaud, and R. Taylor. 2011. "Promotion Systems and Incentives for Adoption of Energy Management Systems in Industry." Institute for Industrial Productivity, Washington, DC, United States.

Gouldson, A., S. Colenbrander, F. McAnulla, A. Sudmant, N. Kerr, P. Sakai, S. Hall, E. Papargyropoulou, and J. Kuylenstierna. 2014. "The Economic Case for Low Cities." The New Climate Economy Report background paper, Global Commission on the Economy and Climate. http://www.newclimateeconomy.net.

Greenpeace. 2014. "2013 Rankings of Urban $PM_{2.5}$ Released, China Must Take Action against Smog" (in Chinese). http://www.greenpeace.org/china/zh/news/releases/climate-energy/2014/01/PM25-ranking/.

Grip, C.E., E. Sandstrom, R. Gebart, and J. Karlsson. 2010. "Industrial Ecology in Northern Areas, Practical Experience and Development." Fourth International Seminar on Society and Materials, Nancy, France, April 28-29, 2010.

Grubler, A., X.M. Bai, T. Buettner, S. Dhakal, D. Fisk, T. Ichinose, J. Keirstead, G. Sammer, D. Satterthwaite, N.B. Shulz, N. Shah, J. Steinberger, et al. 2012. "Urban Energy Systems" in *Global Energy Assessment*, edited by T.J. Johannson, A. Patwardhan, N. Nakicenovic, and L. Gomez-Echeverri, 1307-1400. Cambridge, United Kingdom: Cambridge University Press.

Guan, D.B. and Z. Liu. 2013. *Tracing Back the Smog: Source Analysis and Control Strategies for PM82.5 Pollution in Beijing-Tianjin-Hebei*. Beijing: China Environment Press.

Guttikunda, S. and P. Jawahar. 2012. "Application of SIM-Air Modeling Tools to Assess Air Quality in Indian Cities." *Atmospheric Environment* 62: 551-561.

Guttikunda, S. and M. Khaliquzzaman. 2013. "Health Benefits of Adapting Cleaner Brick Manufacturing Technologies in Bangladesh." Air Qual Atmos Health 7: 103-112.

Guttikunda, S., B. Begum, and Z. Wadud. 2013. "Particulate Pollution from Brick Kiln Clusters in the Greater Dhaka Region, Bangladesh." *Air Qual Atmos Health* 6: 357-365.

Guttikunda, S., R. Goel, D. Mohan, G. Tiwari, and R. Gadepalli. 2014. "Particulate and Gaseous Emissions in Two Coastal Cities — Chennai and Vishakhapatnam, India." *Air Qual Atmos Health*, doi: 10.1007/s11869-014-0303-6.

He., K., Y. Lei, X. Pan, Y. Zhang, Q. Zhang, and D. Chen. "Co-Benefits from Energy Policies in China." *Energy* 35: 4265-4272.

Holmgren, K. "Role of District-Heating Network as a User of Waste-Heat Supply from Various Sources –The Case of Goteburg." *Applied Energy* 83: 1351-1367.

Hoornweg, D. and M. Freire. 2013. "Building Sustainability in an Urbanizing World: A Partnership Report." World Bank, Urban Development Series Report No. 17, Washington, DC.

IEA (International Energy Agency, OECD). World Energy Statistics and Balances database. doi: 10.1787/enestats-data-en.

IEA. 2012. *World Energy Outlook*. Paris: OECD.

IEA. 2014a. *Capturing the Multiple Benefits of Energy Efficiency*. Paris: OECD.

IEA. 2014b. *World Energy Outlook*. Paris: OECD.

IHME (Institute for Health Metrics and Evaluation, University of Washington). Global Burden of Disease study database. http://www.healthdata.org/gbd.

IIP (Institute for Industrial Productivity). 2013a. "Piloting Energy Management Systems in Dezhou Enterprises." IIP Fact Sheet, Washington, DC, Sept. 2013.

IIP. 2013b. "Waste as Resource: A Win-Win Solution." IIP Fact Sheet, Washington, DC, Sept. 2013.

IIP-IFC (Institute for Industrial Productivity and International Finance Corporation). 2014. "Waste Heat Recovery for the Cement- Sector." http://www.ifc.org/wps/wcm/connect/a87be50044581e9889678dc66d9c728b/IFC+Waste+Heat+Recovery+Report.pdf?MOD=AJPERES.

ILO (International Labor Organization). ILOSTAT database. http://www.ilo.org/ilostat/.

IPCC WGIII (Working Group III, Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx. Cambridge, United Kingdom and New York, NY: Cambridge University Press.

IUE CASS (Institute for Urban and Environmental Studies, Chinese Academy of Social Sciences). 2010. "Study on Low Carbon Development and Green Employment in China." ILO Office for China and Mongolia, Beijing.

Kostka, Genia and William Hobbs. 2012. "Local Energy Efficiency Policy Implementation in China: Bridging the Gap between National Priorities and Local Interests." *The China Quarterly* 211: 765-785.

Li, J., T. Voravate, and Wang L. 2009. "Energy Efficiency Policy in the Cement Sector: A Study of the Impacts of Vertical Shaft Kiln Plants Closing in Shandong Province, China." World Bank, Beijing, China.

Liu, S.J., Chen C.S., and He J.W. 2013. "Ten-year Outlook: Decline of Potential Growth Rate and Start of a New Phase of Growth." Background Paper for China Development Forum, Beijing, March 2013.

Liu, Z., Liang S., Geng Y. , Xue B., Xi F.M., Pan Y., Zhang T.Z., and Tsuyoshi Fujita. 2012. *Energy* 37: 245-254.

Ma, C.B. 2010. "Who Bears the Environmental Burden in China – An Analysis of the Distribution of Industrial Pollution Sources?" *Ecological Economics* 69: 1869–1876.

Matus, K., K.M. Nam, N.E. Selin, L.N. Lamsal, J.M. Reilly, and S. Paltsev. 2012. "Health Damages from Air Pollution in China." *Global Environmental Change* 22: 55-66.

Mennis, J. 2005. "The Distribution and Enforcement of Air Polluting Facilities in New Jersey." *The Professional Geographer* 57: 411-422.

Michaels, G., F. Rauch, and S.J. Redding. 2012. "Urbanization and Structural Transformation." *The Quarterly Journal of Economics* 127: 535-586.

Ostojic, D.R., R.K. Bose, H. Krambeck, J. Lim, and Zhang Y.B. 2013. *Energizing Green Cities in Southeast Asia: Applying Sustainable Urban Energy and Emission Planning*. Washington, DC: World Bank.

Oxford Economics. Custom Cities Data and Forecasting. http://www.oxfordeconomics.com.

Rahman, S.M., Z. Wadud, M.A. Ali, and S. Guttikunda. 2011. "Developing Source Receptor Model (SRM) to Estimate the Grid-Based Particulate Matter Concentration in Dhaka." Fourth Annual Paper Meet and First Civil Engineering Congress, Dhaka, Bangladesh, December 22-24, 2011.

Ramachandra, T.V., K. Sreejith, and H.A. Bharath. 2014. "Sector-Wise Assessment of Carbon Footprint Across Major Cities in India" in *Assessment of Carbon Footprint in Different Industrial Sectors*, edited by S.S. Muthu, 207-267. Singapore: Springer.

Rhodium Group and Alliance to Save Energy. 2013. "American Energy Productivity: The Economic, Environmental, and Security Benefits of Unlocking Energy Efficiency." http://rhg.com/reports/american-energy-productivity.

Rosenthal, S. and W. Strange. 2004. "Evidence on the Nature and Sources of Agglomeration Economies" in *Handbook of Regional and Urban Economics*, Vol. 4, edited by J.V. Henderson and J.F. Thisse, 2129-2171. Amsterdam: Elsevier.

Schoolman, E.D., and C.B. Ma. 2012. "Migration, Class and Environmental Inequality: Exposure to Pollution in China's Jiangsu Province." *Ecological Economics* 75: 140–151.

Seto, K. C., S. Dhakal, A. Bigio, H. Blanco, G. C. Delgado, D. Dewar, L. Huang, A. Inaba, A. Kansal, S. Lwasa, J. E. McMahon, D. B. Müller, J. Murakami, H. Nagendra, and A. Ramaswami. 2014. "Human Settlements, Infrastructure and Spatial Planning" in *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report*, edited by Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx. Cambridge, United Kingdom and New York, NY: Cambridge University Press.

South Africa NPC (National Planning Commission, South Africa). 2012. "National Development Plan 2030: Our Future – Make it Work." http://www.gov.za/issues/national-development-plan-2030.

Taylor, R., G. Draugelis, Z. Yabei, and A. Ang Co. 2010. "Accelerating Energy Conservation in China's Provinces." Report 56416, World Bank, Washington, DC, United States. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/09/01/000333038_20100901232632/Rendered/PDF/564160ESW0whit1in0China1s0Provinces.pdf.

Thambiran, T., and R.D. Diab. 2011. "Air Quality and Climate Change Co-Benefits for the Industrial Sector in Durban, South Africa." *Energy Policy* 39: 6658-6666.

UN DESA (United Nations, Population Division, Department of Economic and Social Affairs). 2014. *World Urbanization Prospects: The 2014 Revision*. http://esa.un.org/unpd/wup/.

UNEP (United Nations Environment Programme). 2011. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*. http://www.unep.org/greeneconomy.

US EPA. 1998. "Climate Wise: Wise Rules for Energy Efficiency, A Toolkit for Estimating Energy Savings and Greenhouse Gas Reductions." Report EPA 231-R-98-014.

Wang, H., R. Zhang, M. Liu, and J. Bi. 2012. "The Carbon Emissions of Chinese Cities." *Atmospheric Chemistry and Physics* 12: 6197-6206.

World Bank. World Development Indicators database. http://databank.worldbank.org.

World Bank. 2013. Urbanization beyond Municipal Boundaries: Nurturing Metropolitan Economies and Connecting Peri-Urban Areas in India. Washington, DC: World Bank.

World Bank-MEP (World Bank and Ministry of Environmental Protection, PRC). 2012. "Integrated Air Pollution Management in China: Developing Particulate Matter Control." World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/11913?show=full.

World Bank-DRC. 2014. *Urban China: Toward Efficient, Inclusive, and Sustainable Urbanization*. Washington, DC: World Bank.

Worrell, E., J.A. Laitner, M. Ruth, and H. Finman. 2003. "Productivity Benefits of Industrial Energy Efficiency Measures." *Energy* 28: 1081-1098.

Zheng J.Y., Zhang L.J, Che W.W., Zheng Z.Z., and Yin S.S. 2009. "A Highly Resolved Temporal and Spatial Air Pollutant Emission Inventory for the Pearl River Delta Region, China and Its Uncertainty Assessment." *Atmospheric Environment* 43: 5112-5122.

Zhou, N. and C.J. Williams. 2013. "An International Review of Eco-City Theory, Indicators, and Case Studies." Lawrence Berkeley National Laboratory report LBNL-6513, Berkeley, CA.

7 Glossary

AFR: Alternative fuels and raw materials

Btoe: Billion tonnes of oil equivalent

CHP: Combined heat and power

CO_2e: Carbon dioxide equivalent

EnMS: Energy management system

GHG: Greenhouse gas

GDP: Gross domestic product

GVA: Gross value added

IPCC: Intergovernmental Panel on Climate Change

MSW: Municipal solid waste

OECD: Organisation for Economic Co-operation and Development

$PM_{2.5}$: Particulate matter with a diameter of 2.5 micrometers or less

WHO: World Health Organization

WHR: Waste heat recovery

The Institute for Industrial Productivity (IIP) is a non-profit organization that works with industry and government to promote best practices in energy efficiency, greenhouse gas reductions, and productivity improvements through a network of policy, technology and finance experts.

Institute for
Industrial
Productivity

Sharing best practices for the low carbon future | **iipnetwork.org**

1615 M Street NW, Suite 280, Washington, DC 20036, USA
info@iipnetwork.org | Twitter.com/iipnetwork