McKinsey Center
for Business
and Environment

C40 CITIES

Focused acceleration:

A strategic approach to climate action in cities to 2030

NOVEMBER 2017

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C40 Cities
C40 Cities connects more than 90 of the world's greatest cities, representing 650+ million people and one quarter of the global economy. Created and led by cities, C40 is focused on tackling climate change and driving urban action that reduces greenhouse gas emissions and climate risks, while increasing the health, wellbeing and economic opportunities of urban citizens.

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EXECUTIVE SUMMARY

There is now widespread recognition in the international community that the commitments made by national governments under the Paris Climate Agreement in 2015 cannot be achieved without concerted action by cities. Fortunately, many mayors have shown strong commitment to tackling climate change and a willingness to collaborate to achieve this goal. C40 Cities, a network of mayors of the world's megacities committed to addressing climate change, responded to the Paris Agreement by publishing an analysis—*Deadline 2020*[1]—of the emission reduction pathway their cities would need to achieve to play their part in keeping global average temperature rise within "safe" limits (below 1.5°C). As individual C40 cities now increase the ambition of their climate plans accordingly, this report takes that work a stage further by analyzing the biggest opportunities for cities to accelerate the reduction of their carbon emissions.

While the technologies and expertise exist to limit the temperature increase to 1.5°C, the challenge is still formidable. With cities already stretched to meet multiple competing priorities, city leaders must determine the critical actions that can change their current emissions trajectory and work proactively with their stakeholders to build and invest in the infrastructure and incentives needed to make significant progress toward those actions. That means prioritizing action around initiatives that catalyze systemic change. For this report, C40 has partnered with The McKinsey Center for Business and Environment to quantitatively assess the biggest opportunities for emissions reduction and what they will mean for different types of cities around the world.

We started with the more than 450 emissions reduction actions identified in *Deadline 2020* and prioritized 12 opportunities across four action areas that have the greatest potential in most global cities to curb emissions and put cities on a 1.5°C pathway through 2030. Our analysis recommends that cities pursue a strategy of "focused acceleration" within these 12 carbon reduction opportunities. This recommendation is based on a proven management approach that more progress can be made by concentrating on a small number of high-value opportunities than by spreading effort over hundreds of potential actions. Success will require cities to find creative ways to tackle operational challenges including aligning stakeholders, supply chains, procurement practices, and financing.

1 *Deadline 2020: How cities will get the job done*, C40 Cities and ARUP, 2016, c40.org.

By implementing a focused acceleration approach, cities could achieve 90 to 100 percent of their 2030 emissions targets and build the knowledge and foundational capabilities needed to reach net zero carbon by 2050. At the same time, the incremental investment required to achieve 2030 emissions targets is significant: roughly $50 to $200 per metric ton of of CO_2 equivalent. However, all opportunities provide a positive return on investment in the mid to long term, whether through direct cash flow for investors (for example, in the case of renewables and efficiency improvements) or broader boosts to economic activity in the city (for example, transit-oriented development). For many opportunities, up-front investments are paid back within five to ten years.

This executive summary provides a short overview of the four action areas—power, buildings, mobility, and waste management. A subsequent high-level look at how cities may differ in their approach to capturing these opportunities serves as a prelude to the full discussion in the body of the report.

DECARBONIZING THE ELECTRICITY GRID

Cities—and the world—cannot achieve a 1.5°C trajectory without a massive expansion of large-scale renewable power generation, known as "decarbonizing the grid." While cities may believe they have little influence over the grid mix, in fact, they often represent a major portion of any local electric utility's customers, potentially giving them significant leverage to shape the emissions profile of the electricity consumed within their metropolitan area. Still, capturing this opportunity will not be easy, and cities cannot do it alone. Utilities and regulators must play a central role in ensuring the overall mix of renewables is appropriately balanced at a system level and that critical components such as energy storage are in place to ensure grid reliability. Nevertheless, cities have an essential role to play by setting clear decarbonization goals, aggregating demand for renewables, promoting energy efficiency, and shifting more urban energy consumption to electricity (especially in transportation and heating). Through focused acceleration, and close collaboration between utilities and regulators, cities could achieve a grid mix of 50 to 70 percent renewables (specifically, solar and wind, balanced with other zero-emission generation source such as hydro) by 2030 depending on local resource characteristics, and market and regulatory structure. This level would capture 35 to 45 percent of the total emissions reductions needed in that time frame at a cost as low as $40 to $80 per megawatt-hour.[2]

OPTIMIZING ENERGY EFFICIENCY IN BUILDINGS

In buildings around the world, heating and cooling account for 35 to 60 percent of total energy demand and, on average, produce nearly 40 percent of emissions. Again, reducing energy use and emissions from buildings will not be easy; it will require significantly more focused effort than most cities have currently undertaken. However, multiple decades of pilots and success stories suggest that focused acceleration in this space can pay off. Several opportunities based on widely available technologies offer the potential to

2 Based on recent tenders for large scale renewables.

By implementing a focused acceleration approach, cities could achieve 90 to 100 percent of the 2030 emissions targets and build the knowledge and foundational capabilities needed to reach zero carbon by 2050.

significantly reduce emissions from buildings. These include raising building standards for new construction, retrofitting building envelopes, upgrading HVAC and water heating technology, and implementing lighting, appliance, and automation improvements. While cities generally have more influence over this area than many others, progress will still require city leaders to work closely with building owners, both residential and commercial, real estate developers, and building occupants. This action area is particularly important; since building stock tends to turn over only every 30 to 50 years, getting it wrong will lock in emissions, and potential costs, for decades. In contrast, getting it right will reduce energy costs—as well as provide more resilient, comfortable spaces to live, work, and play—for city residents through 2050 and beyond. Focused acceleration in this action area can close 20 to 55 percent of the gap between current emissions trends and 2030 abatement targets, depending on the local climate and population growth of the city, at an average cost of $20 to $100 per metric ton of CO_2 equivalent.

ENABLING NEXT-GENERATION MOBILITY

City leaders now have access to an unprecedented range of mobility options. Multiple, reinforcing trends in mobility and land use planning are already transforming the experience of getting around in cities. The key to reducing emissions through these trends is to ensure that all residents have access to a variety of attractive, affordable low-carbon mobility options. The development of complete, compact communities that meet the mobility needs of residents and business is foundational to building stronger cities and enabling next-generation mobility. Transit-oriented development implemented today promotes smart densification through better land use planning, lays the foundation for more multimodal transport and reduced carbon emissions in the long-term. Initiatives to encourage walking and cycling within cities' existing land use patterns as well as targeted enhancement of mass transit, such as the introduction of bus rapid transit (BRT) on main arteries, can collectively start to lower emissions in the short-term. In addition, cities can accelerate emissions reductions by enabling uptake of next-generation vehicles, which take advantage of new electric, shared, connected, and autonomous technologies, and by optimizing freight transport and delivery. Focused acceleration in this action area can contribute emissions reductions equal to 20 to 45 percent of 2030 targets, depending on urban income levels and population density. In the process, these efforts can increase GDP by reducing congestion and transforming the quality of life for residents by alleviating local air pollution and improving equitable access to mobility options.

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IMPROVING WASTE MANAGEMENT

Cities can tackle waste emissions in a resource-effective way by adopting a "highest and best use" approach: first reducing waste upstream; then repurposing as much useful finished product as possible; then recycling, composting, and otherwise recovering materials for use; and finally, managing disposal to minimize emissions of any remaining organic matter. Methane emissions from waste have 86 times the near-term global warming potential of carbon dioxide, making it an urgent priority for preventing the worst effects of climate change, and reducing waste has an outsize impact on the full life cycle emissions of consumption. Innovative models for waste management can help cities rethink their need for traditional collection and disposal infrastructure, and forward-looking cities are already going further and planning the transition to a fully "circular economy," shifting resource consumption from linear flows to continuous reuse. Depending on the starting point of existing waste management services, as well as composition of waste, focused acceleration can achieve up to 10 percent of the emissions reductions needed by 2030, as well as numerous benefits to local resource resilience and health.

Achieving *Deadline 2020* targets will not be easy. Cities will need to ensure they move beyond quick wins to a focused acceleration approach in priority areas.

HOW DIFFERENT CITIES CAN ACHIEVE THEIR CARBON REDUCTION TARGETS

To demonstrate the scale of action needed to achieve 100 percent of a city's emissions reductions target by 2030 through focused acceleration, we have modeled sample road maps for six illustrative city types. These road maps show where different cities could choose to focus and why, along with the critical enablers needed to achieve zero carbon by 2050. As important, these road maps demonstrate the practical impact of focused acceleration across different types of cities.

For example, a Large, Middle-Income, Semi-Dense City could focus on accelerating highly visible initiatives to help residents experience how a low-carbon future looks and feels in everyday life. For such a city the installation of solar power on municipal and suitable private rooftops as well as in community sites would be good demonstration projects. Policies to increase population density in select districts, such as transit-oriented development, new BRT routes, and cycling-friendly street design, could increase density by 6 percent and improve average walkability by 2030. The city might also commit to 100 percent of zero-emission buses by 2030, along with EV-friendly measures such as low-emission zones that help accelerate electrification of personal and commercial vehicles used on city streets.

In contrast, a Small, High-Income, Innovator City has only modest sunlight but abundant wind and hydropower. Because residents are accustomed to many different modes of transport, many have already given up their cars. The city faces cold winters, so heating dominates energy use in commercial and residential buildings. To build on this strong foundation, the city seeks to create a grid mix of 70 percent centralized renewables by 2030. In mobility, it sets a target of 100 percent zero-emission buses, while promoting car sharing and connected technologies. The city's efforts also include achieving one or more types of energy efficiency retrofits in 100 percent of privately owned buildings by 2030.

How potential initiatives for these two cities compare is shown in Exhibit A. Exhibits B and C compare a Middle-Income Mega City with a Large, Low-Income, Leapfrog City, and a Large, High-Income, Dense City with a Low-Income Mega City respectively. Whether cities are in the early stages of developing and implementing their carbon reduction programs or contemplating how to build on their existing robust efforts, these road maps can serve as illustrations of how they might choose to maximize the benefits of carbon reduction efforts across the 12 priority opportunities identified in this report.

MOVING FORWARD

Achieving *Deadline 2020* targets will not be easy. Cities will need to ensure they move beyond quick wins to a focused acceleration approach in priority areas. Furthermore, cross-sector partnerships will be essential both to successfully capture the opportunities as well as to ensure that city initiatives incorporate system-level considerations, especially in grid decarbonization. The opportunities laid out in this report will generate a wide range of benefits beyond carbon emissions—from reduced congestion, better public health, and greater productivity to improved quality of life and increased resilience. Highlighting the economic and social benefits of jobs, reduced air pollution, improved road safety, and reclaimed commute time can help mayors make the case for investments today in our collective future.

The action areas laid out in this report represent the first phase of carbon reduction strategies. Cities that build a world-class tool kit to capture these opportunities, including streamlined procurement, access to capital, relationships with other cities to learn from their best-practice experiences, and partnerships with the private sector and government, will be well positioned to tackle the next set of emissions reduction opportunities. Achieving 2030 target reductions will also lay the foundation to pursue opportunities that take longer to play out—such as densification and land use planning—but will be critical in achieving the deeper decarbonization required to meet 2050 targets.

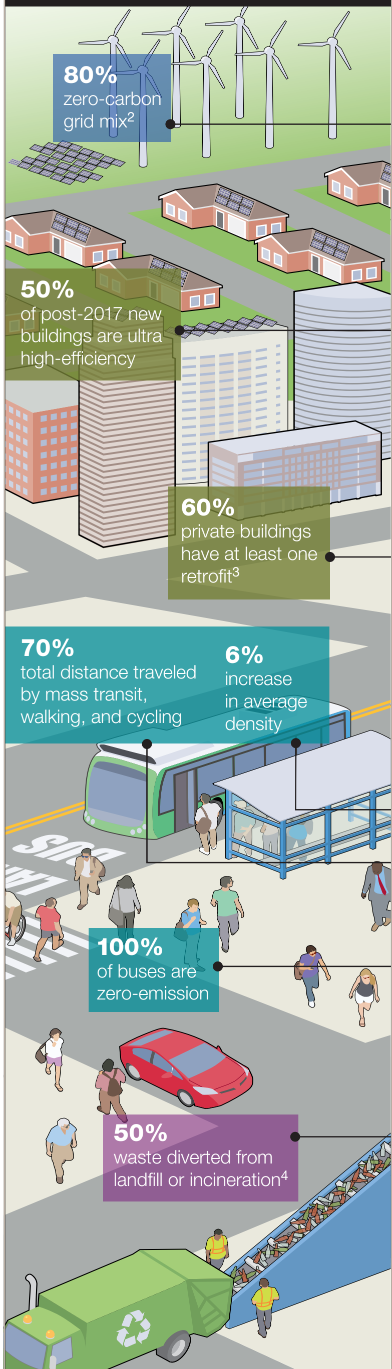
With climate action as a top priority, this report offers a viable way forward for cities of all sizes and means. Progress will require summoning the will, leadership, and commitment to make progress, but having a defined path forward will be a critical advantage. ■

Exhibit A

Comparing potential emissions impact and level of adoption by 2030 between two city types

Emissions reduction potential
Percent of 2030 target[1]

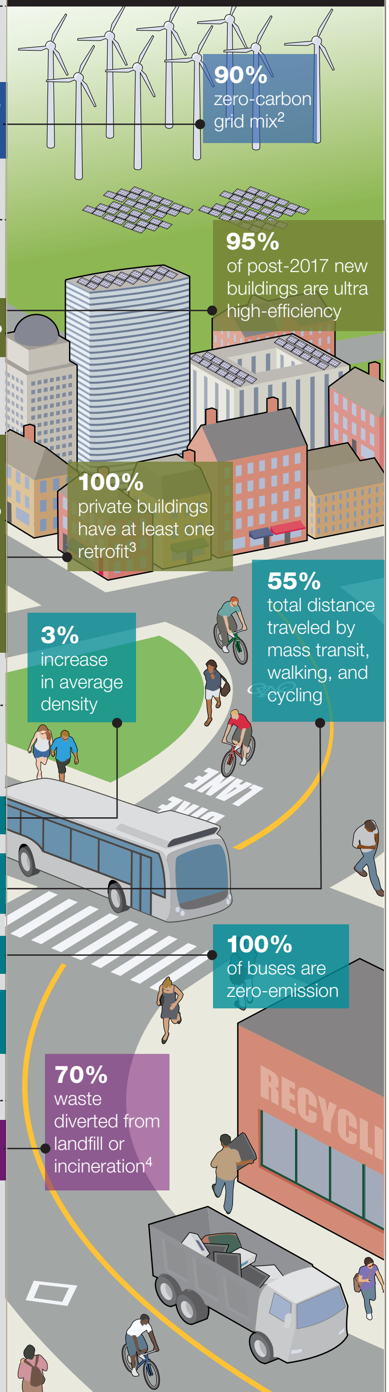
Large, Middle-Income, Semi-Dense City (Potential level of adoption)		Small, High-Income, Innovator City (Potential level of adoption)
	Decarbonizing the electricity grid	
10%	Centralized renewables	54%
24%	Distributed renewables	7%
	Optimizing energy use in buildings	
10%	Ultra high-efficiency new building standards	13%
0%	Building envelope retrofits	9%
8%	HVAC and water heating upgrades	26%
3%	Lighting upgrades	3%
0%	Building automation and controls	2%
	Enabling next-generation mobility	
5%	Transit-oriented development	2%
8%	Mass transit, walking, and cycling infrastructure	4%
23%	Next-generation vehicles	11%
2%	Commercial freight optimization	1%
7%	**Improving waste management**	6%



Critical enablers[5]

Decarbonizing the electricity grid: Investments in grid flexibility and balanced generation mix

Enabling next-generation mobility: Master planning for land use and transit infrastructure



Critical enablers[5]

Decarbonizing the electricity grid: Investment in grid flexibility to manage large demand and supply shifts

Optimizing energy use in buildings: Market development for retrofit innovations

1 Emissions reduction potential for a specific city will vary based on current city carbon footprint and *Deadline 2020* emissions reduction target for 2030.

2 Assumes balanced system grid mix that may include solar, wind, hydro and other zero-carbon generation sources.

3 Buildings with one or more of: full envelope or windows-and-roof retrofit, HVAC or water heating upgrade, automation and controls installed.

4 Assumes universal waste collection in place as prerequisite.

5 Examples—not exhaustive.

SOURCE: McKinsey analysis

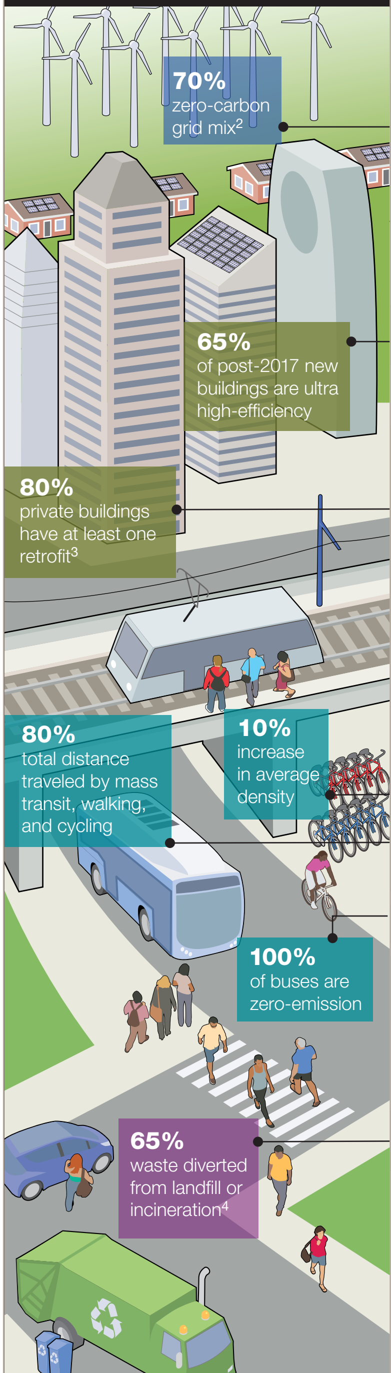
Illustrations by Vic Kulihin

Exhibit B **Comparing potential emissions impact and level of adoption by 2030 between two city types**

Emissions reduction potential
Percent of 2030 target[1]

Middle-Income Mega City (Potential level of adoption)		Large, Low-Income, Leapfrog City (Potential level of adoption)
	Decarbonizing the electricity grid	
21%	Centralized renewables	7%
15%	Distributed renewables	36%
	Optimizing energy use in buildings	
22%	Ultra high-efficiency new building standards	23%
1%	Building envelope retrofits	0%
6%	HVAC and water heating upgrades	2%
5%	Lighting upgrades	11%
1%	Building automation and controls	1%
	Enabling next-generation mobility	
6%	Transit-oriented development	13%
5%	Mass transit, walking, and cycling infrastructure	18%
8%	Next-generation vehicles	8%
2%	Commercial freight optimization	6%
6%	**Improving waste management**	5%

Middle-Income Mega City
Potential level of adoption

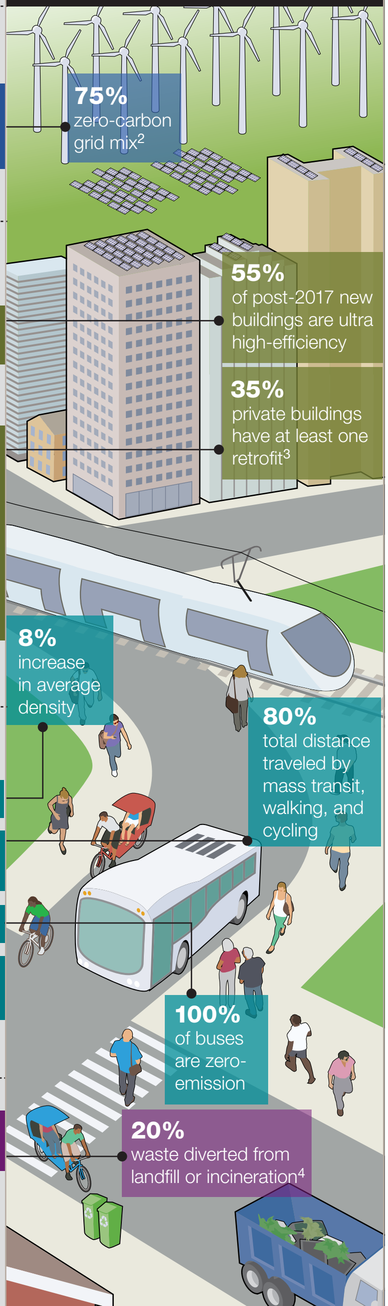


Critical enablers[5]

Decarbonizing the electricity grid: Investment in grid flexibility to manage large demand and supply shifts

Optimizing energy use in buildings: Market development for ultra high-efficiency construction

Large, Low-Income, Leapfrog City
Potential level of adoption



Critical enablers[5]

Decarbonizing the electricity grid: Investments in grid flexibility, microgrids and storage

Optimizing energy use in buildings: Market development for ultra high efficiency construction

Enabling next-generation mobility: Master planning for land use and transit infrastructure

Illustrations by Vic Kulihin

SOURCE: McKinsey analysis

[1] Emissions reduction potential for a specific city will vary based on current city carbon footprint and *Deadline 2020* emissions reduction target for 2030.

[2] Assumes balanced system grid mix that may include solar, wind, hydro and other zero-carbon generation sources.

[3] Buildings with one or more of: full envelope or windows-and-roof retrofit, HVAC or water heating upgrade, automation and controls installed.

[4] Assumes universal waste collection in place as prerequisite.

[5] Examples—not exhaustive.

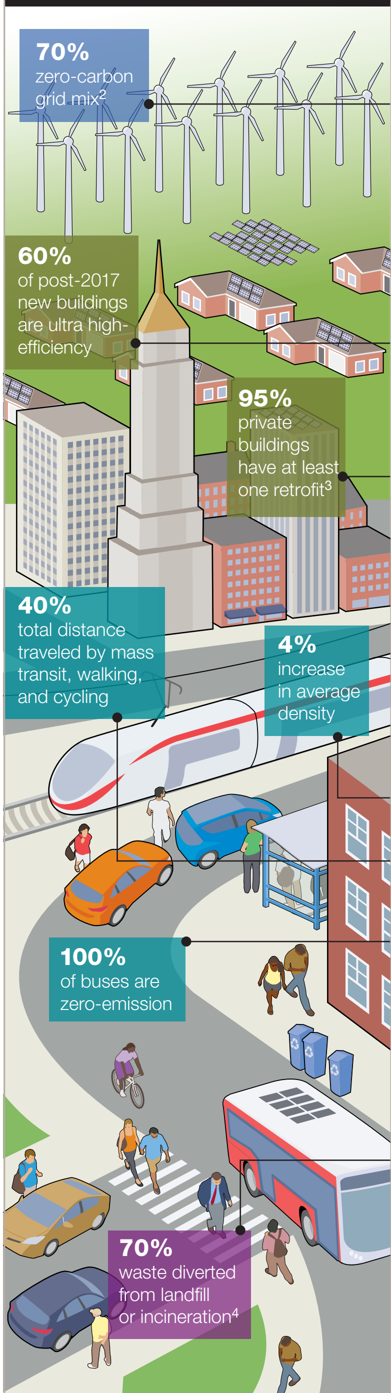
Exhibit C

Comparing potential emissions impact and level of adoption by 2030 between two city types

Emissions reduction potential
Percent of 2030 target[1]

Large, High-Income, Dense City (Potential level of adoption)	Emissions reduction potential	Low-Income Mega City (Potential level of adoption)
	Decarbonizing the electricity grid	
18%	Centralized renewables	3%
7%	Distributed renewables	40%
	Optimizing energy use in buildings	
2%	Ultra high-efficiency new building standards	22%
6%	Building envelope retrofits	0%
24%	HVAC and water heating upgrades	1%
2%	Lighting upgrades	9%
3%	Building automation and controls	1%
	Enabling next-generation mobility	
4%	Transit-oriented development	13%
5%	Mass transit, walking, and cycling infrastructure	14%
13%	Next-generation vehicles	15%
1%	Commercial freight optimization	3%
4%	**Improving waste management**	5%

Large, High-Income, Dense City
Potential level of adoption

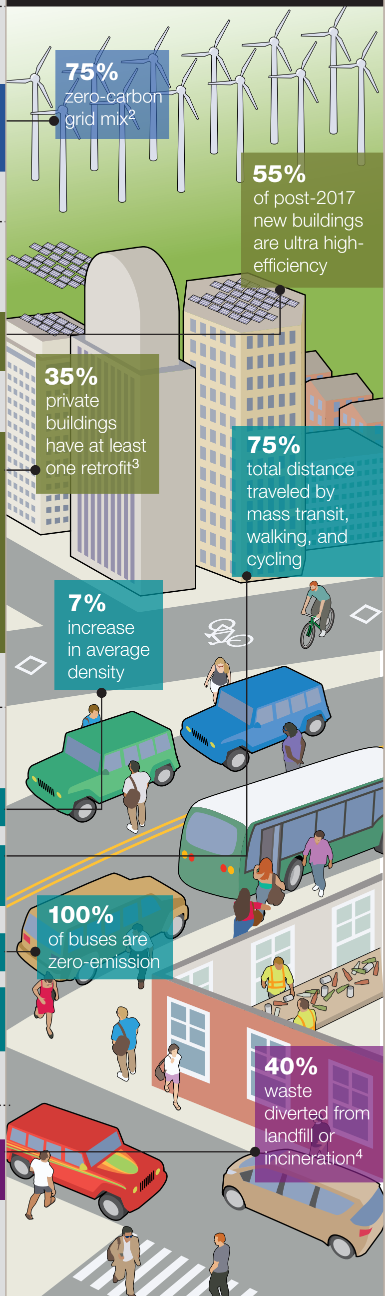


Critical enablers[5]

Decarbonizing the electricity grid:
Investment in grid flexibility to manage large demand and supply shifts

Optimizing energy use in buildings:
Phase out of oil or gas heating systems

Low-Income Mega City
Potential level of adoption



Critical enablers[5]

Decarbonizing the electricity grid:
Investments in grid flexibility, microgrids, and storage

Optimizing energy use in buildings:
Market development for ultra high-efficiency construction

Enabling next-generation mobility:
Master planning for land use and transit infrastructure

Illustrations by Vic Kulihin

[1] Emissions reduction potential for a specific city will vary based on current city carbon footprint and *Deadline 2020* emissions reduction target for 2030.

[2] Assumes balanced system grid mix that may include solar, wind, hydro and other zero-carbon generation sources.

[3] Buildings with one or more of: full envelope or windows-and-roof retrofit, HVAC or water heating upgrade, automation and controls installed.

[4] Assumes universal waste collection in place as prerequisite.

[5] Examples—not exhaustive.

SOURCE: McKinsey analysis

Chapter 1

THE GROWING ROLE OF CITIES IN CLIMATE ACTION

Cities have been the hubs of commerce, culture, and innovation for centuries. More recently, urban centers have emerged as important advocates for global action on climate change. Several trends account for their increased profile and influence. Around the world, urbanization is on the rise: by 2050, 70 percent of the world's population will live in metropolitan areas, with much of the migration occurring in developing nations.[1] The flow of humanity from rural to urban areas is happening on a dizzying scale. Consider that more than 65 million people—equal to eight Londons—relocate to cities each year. This population growth has reinforced the position of cities as the engine of the global economy, accounting for more than 80 percent of world GDP.[2] Traditional powerhouses such as London, New York City, Singapore, and Tokyo are being joined by new entrants such as Mumbai and Shanghai, with the latter category of cities emblematic of the rapid growth in emerging nations.

People are moving to cities for greater access to jobs, education, and healthcare, but their migration will also strain current systems. As the cranes that dot the skyline of any major growing city attest, rising urban populations require new buildings, expanded transportation systems, and new energy infrastructure. All of this activity, from business and commuting to construction and daily living, means that urban centers consume over two-thirds of global energy and emit more than 70 percent of the world's total greenhouse gases.[3] This concentration means that reducing emissions globally requires reducing emissions in cities.

Around the world, city leaders are experimenting with initiatives focused on energy efficiency, renewable energy, and sustainability. They are launching and scaling innovative programs covering a wide range of challenges including reducing energy consumption, decreasing congestion, controlling air pollution, and improving the quality of life for residents. Solutions facilitating multimodal travel, recycling, bike-sharing programs, and transit-oriented residential and commercial development are just a few of the myriad efforts being pursued by cities.

1 "Human population: Urbanization," *Population Reference Bureau*, 2007, pbr.org.

2 *Urban world: Mapping the economic power of cities*, McKinsey Global Institute, 2011, McKinsey.com.

3 "Why cities?" C40 Cities, accessed October 30, 2017, c40.org.

> Our analysis suggests that "focused acceleration"—putting the majority of effort and resources toward implementing a handful of solutions—will be critical to making sustained progress.

Many cities are also demanding a seat at the table in an effort to shape global environmental policy. At the COP21 conference in Paris in 2015, 195 nations committed to hold the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C.[4] Many of the world's largest cities also pledged to do their part, recognizing that they can be more agile and responsive than other levels of government, and that local actions, such as land use planning and building retrofits, have long-term implications for global emissions. In 2016, C40 released *Deadline 2020*, a report that lays out indicative pathways for cities to meet the commitments of the Paris Agreement by reducing their emissions over time, converging on a long-term goal of net zero emissions. The challenge is formidable: wealthier cities must reduce per capita emissions by 70 to 80 percent, and lower-income cities must hold absolute emissions steady as they manage rapid growth over the same period.

Achieving these targets will require much more than setting goals. Cities will need to roll up their sleeves and actively build and invest in the infrastructure and incentives needed to make significant progress. They cannot do it alone, but they can lead the way, and they must act today.

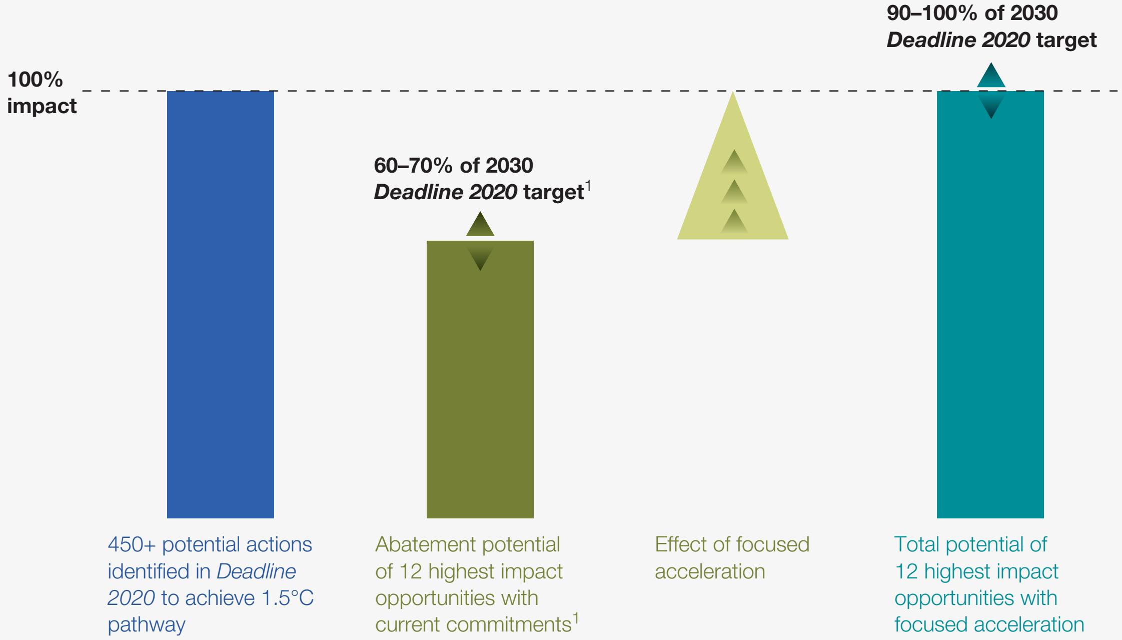
THE CASE FOR FOCUSED ACCELERATION

When it comes to climate action, the challenge for many cities is understanding where to focus. *Deadline 2020* identifies more than 450 actions that cities can take to reduce their emissions. However, without clarity on top priorities, city leaders may fall into the trap of spreading their attention and resources across many small areas rather than identifying the most valuable opportunities to achieve deep emissions reductions. This fragmented approach may provide short-term payoffs as cities capture the lowest-hanging fruit, but it will not be enough in the long run and may set city leaders down the wrong path.

Our analysis suggests that "focused acceleration"—putting the majority of effort and resources toward implementing a handful of solutions—will be critical to making sustained progress. Focused acceleration is a proven approach in the private sector. We have found companies that focus change efforts on a few big opportunities and execute them well, rather than skimming the surface of many smaller initiatives, achieve more dramatic results and do so faster (Exhibit 1). We propose a short list of 12 opportunities for cities to accelerate in a focused way. (The mix varies by city type, and this report outlines how to determine

4 Coral Davenport, "Nations approve landmark climate accord in Paris," *New York Times*, December 12, 2015, nytimes.com.

Exhibit 1 **Implications of focused acceleration**



1 Assumes current commitments by C40 Cities with climate action plans are met.

SOURCE: McKinsey analysis

the ideal path.) We believe that focused acceleration of these opportunities will ensure that cities not only capture the level of emissions reductions needed to achieve their 2030 emissions targets but also develop the experience and foundational capabilities needed to reach net zero carbon emissions by 2050.

While our analysis shows that meeting *Deadline 2020* targets is achievable for the majority of cities, collaboration will be critical. In many cases, cities will need to go beyond traditional boundaries of city influence and decision-making power. Utilities, real estate owners, transport providers, financial institutions, citizens, nongovernmental organizations, and other stakeholders all have a part to play in achieving reaching emissions targets, so city officials will need to take decisive action to get stakeholder support to capture the inherent opportunity. Mayors and elected officials can use their convening power, provide incentives for private investments, demand change beyond their jurisdictional boundaries, and share and apply approaches drawn from innovative governments and organizations around the world to make the required progress.

The chapters that follow offer an overview of the biggest opportunities for cities to focus on. We also provide example road maps showing how different city types can reach their climate goals in the coming years. ■

Chapter 2

THE BIGGEST OPPORTUNITIES FOR CLIMATE ACTION IN CITIES

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To help the leaders of different cities understand how they can effectively pursue a focused acceleration strategy, we assessed the full spectrum of opportunities to reduce city emissions and modeled the potential emissions reductions from the highest impact opportunities for six illustrative city types (Exhibit 2). The resulting city road maps provide insights on where different cities might focus their efforts and why, along with some of the critical enablers needed to achieve zero carbon by 2050.

The model accounts for interdependencies between different emissions reduction opportunities, such as shifts across different transport modes, and the effect of added renewable generation on the emissions intensity of electric technologies. Our analysis also incorporates key city characteristics, such as income growth, transit ridership, and building mix, to ensure contextual differences are considered. We then applied levels of adoption of these opportunities that we believe can be achieved by 2030 in a focused acceleration scenario, based on trends in cost and feasibility gleaned from industry and case studies of leading cities. Finally, we compared the resulting emissions impact for each illustrative city type with the reductions needed to meet its 1.5°C trajectory as indicated in *Deadline 2020*.

Our analysis reveals that the biggest opportunities to act on by 2030 for most cities reside in four primary action areas—decarbonizing the electricity grid, optimizing energy use in buildings, enabling next-generation mobility (including better land use planning), and improving waste management—which in turn reveal 12 opportunities (Exhibit 3). To ensure these opportunities are also compatible with achieving net zero emissions by 2050, we focused on solutions that both reduce emissions in the near term and lay the foundation for a zero-carbon future. As a result, the analysis prioritizes electrification and renewables over “bridging” technologies such as natural gas power generation and vehicles that run on biofuels.

With focused acceleration, the 12 opportunities have the potential to achieve 90 to 100 percent of the emissions reductions needed within the 2030 time frame, depending on city context. At the same time, this research shows that the incremental investment needed to achieve 2030 emissions targets is significant: roughly $50 to $200 per metric ton of CO_2 equivalent, on average—an outlay in the tens of billions of dollars for an individual city by 2030. However, all opportunities achieve positive economic results in the mid to long term, whether through direct cash flow for investors (for example, in the case of renewables

Exhibit 2

Six illustrative city types flex analysis and highlight critical considerations for different individual cities

Large, Middle-Income, Semi-Dense City

Semi-dense, moderate growth in **income** and **population**

Moderate city powers, limited history of climate action and data

Carbon-intensive grid with limited decarbonization planned, high solar radiation

Rising cooling demand in buildings as incomes and temperatures rise

Partial transit system (eg, BRT), low car ownership but expected to grow

Established waste collection but no diversion or emissions reduction

Small, High-Income, Innovator City

Low density and **slow-growing income** and **population**

Significant city powers, extensive history of climate action and data collection

Decarbonized grid with further push planned, low solar radiation

Ultra high efficiency standards in place for building construction/ equipment

Extensive transit system with connections to walking and cycling and shared mobility services

Advanced waste management with high diversion, reliance on incineration

Large, High-Income, Dense City

Dense and **slow-growing income** and **population**

Moderate city powers, history of climate action with good data collection

Decarbonizing grid (regional or national priority), moderate solar radiation

Space heating 50% of building energy demand, mostly fueled by inexpensive oil or gas

Extensive yet **aging transit system,** growing shared mobility

Advanced waste management with some emissions reduction

Low-Income Mega City

Dense and **fast-growing income** and **population**

Limited city powers, no prior history of climate action or data collection

Carbon-intensive grid with limited decarbonization planned, high solar radiation

Rapid growth in new builds and cooling demand per m2

High share of nonmotorized transport and walking, new and limited transit system, car use and ownership expected to grow

Limited waste collection and no emissions management

Middle-Income Mega City

Semi-dense and **fast-growing population**

Significant city powers tied to national priorities, some climate action and data collection

Coal-dependent grid but rapid decarbonization planned, moderate solar radiation

Rapid growth in new builds with low average efficiency, high adoption of solar water heating

New and **extensive transit system**

Established waste collection, reliance on incineration for disposal

Large, Low-Income, Leapfrog City

Semi-dense and **very fast-growing income** and **population** (double size by 2030)

Limited city powers, no prior history of climate action and data collection

Coal-dependent grid with limited decarbonization planned, high solar radiation

Rapid growth in new builds and energy intensity of buildings as incomes rise

High share of nonmotorized transport and walking, very limited transit system, car use and ownership expected to grow rapidly

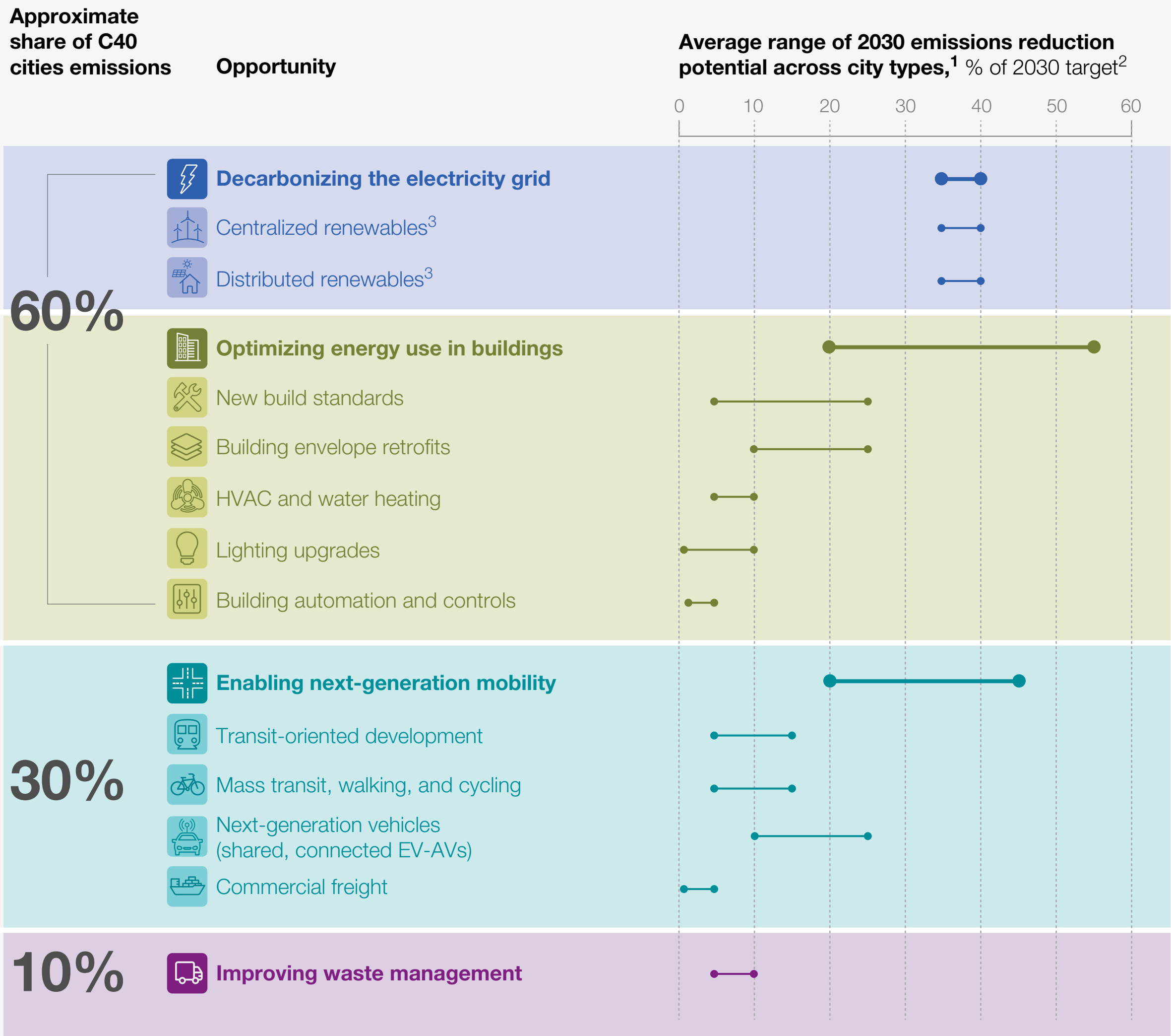
Limited waste collection and no emissions management

SOURCE: McKinsey analysis

and efficiency improvements) or broader boosts to economic activity in the city (for example, in the case of transit-oriented development) in addition to public health and other quality of life benefits. For many opportunities, our analysis shows that up-front investments are paid back within five to ten years (Exhibit 4).

The model we created determines the emissions reduction potential of these four action areas in different types of cities. However, cities are not adopting them at sufficient speed and scale. At current rates of implementation and adoption, based on existing policies and market trends, these 12 opportunities are set to deliver only 20 to 50 percent of the emissions through 2030 indicated by *Deadline 2020*—far less than their potential. Many cities with climate action plans in place are currently falling short of a 1.5°C trajectory.

Exhibit 3 **Top 12 opportunities by action area**

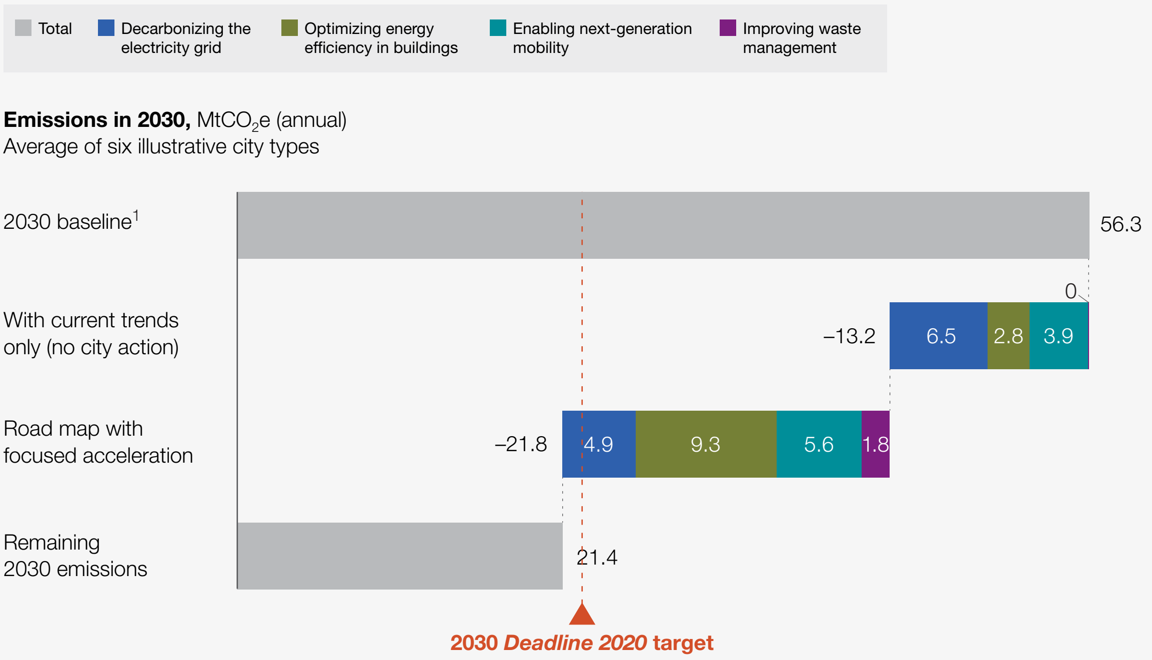


[1] Emissions reduction potential as modeled for a "focused acceleration" scenario across 6 illustrative city types, with highest and lowest outliers removed.
[2] 2030 target is based on *Deadline 2020* pathways for specific city types.
[3] Percentages given are for system level mix. Balance between centralized and distributed generation will vary by region.

SOURCE: McKinsey analysis

Exhibit 4

Impact of focused acceleration vs. current trends



[1] Assumes technologies and policies remain fixed from 2015

SOURCE: McKinsey analysis

Achieving an emissions trajectory compatible with the 1.5°C target by 2030 and doing so in a way that sets the stage for net zero carbon emissions by 2050, will not be easy; cities will need a clear vision, sustained commitment, and significant investment. However, we believe that the majority of cities can achieve full compliance with *Deadline 2020* emissions reductions if they pursue a strategy of focused acceleration centered on these 12 opportunities. Moreover, these efforts will put in place much of the infrastructure needed to reach zero-carbon emissions by 2050. Because every city has different characteristics, the level of focus on each of these 12 opportunities will differ. For example, a mature urban center in a developed country has a different emissions profile than a rapidly growing city in a developing nation. In general, a handful of factors—such as regulatory context, geography, climate, income levels, and population density—will shape the optimal approach for each city.

In the following sections we assess each of the four action areas, including considerations for capturing value from each opportunity, key factors that account for differences across cities, and illustrations of approaches that different types of cities could take to achieve the necessary emissions reductions by 2030.

CHAPTER 2.1:

Decarbonizing the electricity grid

Cities—and the world—cannot achieve a 1.5°C trajectory without a massive expansion of renewable power generation, known as "decarbonizing the grid." As more and more of a city's vital functions come to run on electricity, from basics such as refrigeration and lighting all the way to electric vehicles (EVs) and wireless connectivity for the Internet of Things, ensuring a supply of clean, low-carbon power becomes critical.

Cities cannot independently decarbonize the grid; utilities and regulators must play a central role in managing the mix and build-out of renewables at the system or regional level. Their involvement is required because the overall mix of renewables on the grid must be appropriately balanced (for example, to avoid excessive generation or shortages at certain times of day or during certain seasons), and critical components such as storage must be in place to ensure the system stays reliable through shifts in supply and demand. These challenges are technically and economically complex and will require thoughtful planning by utilities and support from state and national regulatory agencies, though solutions do exist.

Still, cities have an essential role to play in encouraging the build-out of renewables. Some cities might deprioritize pushing for cleaner electricity, believing they have little influence over the grid mix, when in reality they represent a major portion of any local electric utility's customers; this influence provides significant leverage to shape the emissions profile of the electricity consumed within a city's metropolitan area. By setting clear decarbonization goals, aggregating demand for renewables, shifting more urban energy consumption to electricity (especially in transportation and heating), and improving load management, cities can help utilities navigate the path to a highly electrified, renewables-powered future. Through execution of focused acceleration and close collaboration, utilities, regulators, and cities could achieve a grid mix of 50 to 70 percent renewables by 2030. Depending on the characteristics of the city, this mix is equivalent to achieving 35 to 45 percent of the total emissions reductions needed in that time frame through grid decarbonization alone.

The opportunities

Renewable energy is already the fastest-growing type of electricity generation around the world, with approximately 135 gigawatts of renewable capacity installed in 2016[5]—about enough to meet the electricity demand of the entire United Kingdom, or six New Yorks. Rapidly improving costs are driving the trend: since 2009 the total installed costs of solar and offshore wind have fallen by as much as 70 percent around the world, with onshore wind costs on course to drop by 50 percent through 2030.[6] New power purchase agreements (PPAs) for solar now frequently fall below $100 per megawatt-hour, with some reaching less than $30, putting solar at or below the cost of a new natural gas plant, and

5 *Global trends in renewable energy investment 2017*, Frankfurt School, UNEP Collaborating Centre, 2017, fs-unep-centre.org.

6 David Frankel, Aaron Perrine, and Dickon Pinner, "How solar energy can (finally) create value," October 2016, McKinsey.com ; Katherine Dykes, Maureen Hand, Eric Lantz, et al., *Enabling the SMART wind power plant of the future through science-based innovation*, National Renewable Energy Laboratory (NREL), 2017, nrel.gov.

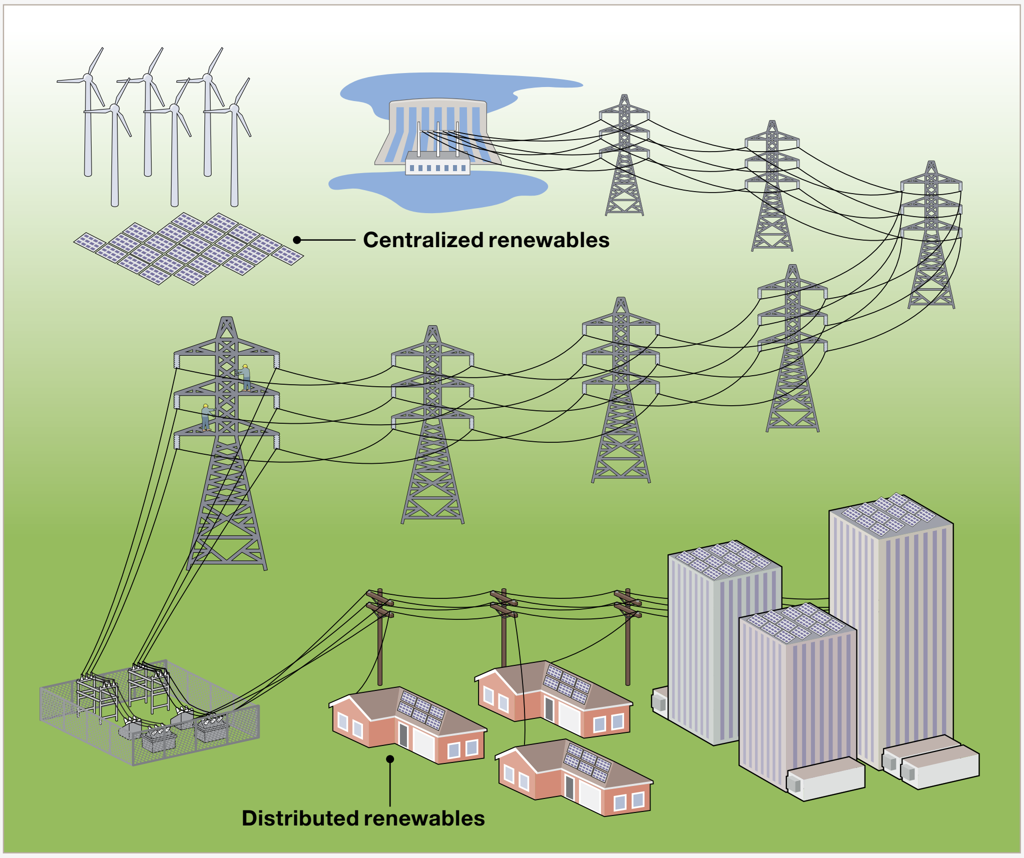
soon will be at or below the marginal cost of generation for most fossil fuel power plants. In many contexts, it is now cheaper to bring new solar generation online than to continue to operate existing coal plants[7] (Exhibit 5).

Still, the challenge is considerable: to meet 2030 emissions targets, new renewables projects will need to come online at two to three times the current rate of development. Cities can play a crucial role in helping their utilities to accelerate grid decarbonization on two fronts: investing in massive expansion of centralized renewables and enabling smart expansion of distributed renewables.

Invest in massive expansion of centralized renewables. Large-scale wind, solar, and other zero-carbon power generation methods are often the most cost-effective ways to rapidly decarbonize the grid, with recent tenders coming in as low as $40 to $80 per megawatt-hour. These renewable power plants can employ advanced technology such as

7 David Frankel, Aaron Perrine, and Dickon Pinner, October 2016, McKinsey.com.

Exhibit 5



Centralized renewables
Large-scale solar or wind farms, or other renewable generation outside the city

Distributed renewables
Smaller-scale renewable generation within the city, usually community or rooftop solar PV

Illustration by Vic Kulihin

sun-tracking solar photovoltaic (PV) panels and larger turbines for wind and be located where the renewable resource is most abundant. For some types of renewables such as offshore wind, centralized generation is the minimum cost-effective scale.

Cities around the world have shown they can lead the way on massive expansion of centralized renewables. In our analysis, we modeled the ability of cities to help shift the total grid mix toward renewables beyond existing state or national commitments through 2030, based on the successes of cities such as Copenhagen, Melbourne, and San Francisco.

Enable smart expansion of distributed renewables. While centralized renewables have clear economies of scale, distributed renewables such as rooftop and community-scale solar PV and also have an important role to play. In situations where centralized renewables would require the expensive build-out of transmission or distribution infrastructure, smaller installations closer to or within cities may be more economical for utilities and potentially faster to implement. For example, New York City's utility Con Edison has opted to invest $200 million in distributed renewables and demand reduction technologies, enabling it to postpone construction of a new $1.2 billion substation.[8] On-site generation such as rooftop solar PV, when coupled with on-site storage, can help alleviate spikes in energy demand—such as during hot summer days when office buildings heavily run air conditioning—that could otherwise require an expensive build-out of centralized peak-load capacity. For example, available sites for large-scale solar or wind farms may be far away from urban centers, while smaller sites nearby may be suitable for community-scale projects or even modest utility-scale installations.

Energy resilience is also an important consideration for cities, especially as climate change and other threats to grid resilience push the limits of centralized systems. Distributed renewables, combined with microgrids and local energy storage, could enable cities to bring power back online quickly after natural disasters and other disruptions to centralized electricity service. Lower-income cities—where centralized grids are often unreliable and difficult to expand quickly enough to meet electricity needs of a growing urban population—have a specific interest in distributed renewables. For example, in China and India, residential rooftop solar PV is close to cost-competitive with power generated by gas-fired power stations.[9] Solar could also have additional benefits for emissions reduction and air quality by replacing kerosene for lighting and cooking and making diesel generators less necessary for backup power.[10]

The cost of distributed renewables continues to decrease alongside centralized renewables, and even small installations such as residential rooftop solar can pay back investments within five to ten years. This trend makes distributed renewables one of the more cost-effective ways to reduce city emissions, at around $40 to $150 per metric ton of CO_2 equivalent depending on regional availability and labor costs. Community-scale

8 Gavin Bade, "ConEd Brooklyn-Queens non-wire alternative project installs first microgrid," *Utility Dive*, December 14, 2016, utilitydive.com.

9 Sarah Martin, David Satterthwaite, Michael I. Westphal, et. al., *Powering cities in the global south: How energy access for all benefits the economy and the environment*, World Resources Institute, September 2017, wri.org.

10 Sarah Martin, David Satterthwaite, Michael I. Westphal, et. al., World Resource Institute, September 2017, wri.org.

installations can yield further cost improvement through economies of scale, and when coupled with microgrids and local storage can improve the resilience of whole districts.

However, it's critical to note the significant disruptions to grid reliability that can occur at such high levels of distributed generation, especially from a single type of renewable resource such as solar, unless broader system integration issues are also addressed. It will be essential to ensure that the overall grid mix is appropriately balanced and that storage and other mechanisms are in place to support sufficient dispatchable capacity and system flexibility to handle fluctuations in supply.

Breaking down barriers: How acceleration is possible

Cities, utilities, and regulators can take advantage of declining costs and improved availability of renewables to catalyze a rapid build-out over the next decade. The most straightforward method is to facilitate direct investment in, or purchase of, renewable energy. The City of Copenhagen, for example, launched a cooperative through its own utility to invest in a 40-megawatt wind farm just two kilometers off its coast. The cooperative attracted more than eight thousand investors in the local community, which helped overcome resistance to building a large energy facility close by. Denmark's national energy producer, Ørsted (formerly DONG Energy), also has an ownership stake and the electricity produced is sold nationally as well as within Copenhagen, helping Denmark progress toward its goal of supplying 50 percent of total electricity with offshore wind.[11]

Even cities with less-favorable conditions for renewables have found innovative ways to decarbonize their electricity supply. The City of Melbourne in Australia receives its energy supply from a utility operating on 90 percent coal power generation, high-rises dominate the city core, and there is limited potential for on-site renewables. It also represents a small portion of the region's overall energy demand.[12] Working within existing national policy, the city developed a group energy procurement model and joined forces with other city governments, cultural and educational institutions, and businesses in the area to purchase 110 gigawatt-hours of new renewable electricity over ten years.[13] In Boston, local institutions and developers took the lead: the Massachusetts Institute of Technology, Boston Medical Center, and Post Office Square Redevelopment Corporation came together to finance a 60-megawatt solar farm through a PPA by committing to purchase 100 percent of the energy generated from the facility for 25 years. The solar farm is located in North Carolina where 40 percent of electricity generation is coal-fired; the new solar capacity accelerated decarbonization of North Carolina's grid and enabled a nearby coal-fired plant to retire ahead of schedule.[14] These developments are small initial steps compared with

11 " Wind turbine co-operatives (Middelgrunden Vindmøllelaug)," State of Green, accessed October 30, 2017, stateofgreen.com; "DONG Energy celebrates 1000 wind turbines at sea," Ørsted, October 25, 2016, orsted.com; "A world-leader in wind energy," Denmark: The official site of Denmark, November 2015, denmark.dk.

12 "Cities100: Melbourne—Teaming up to buy renewable energy," Cities100, October 30, 2015, c40.org.

13 "Melbourne Renewable Energy Project," City of Melbourne, accessed October 30, 2017, Melbourne.vic.gov.au.

14 David L. Chandler, "MIT's solar plant is delivering on its promises," *MIT News*, March 23, 2017, new.mit.edu; "Summit farms: Investing in off-site renewable energy," MIT Office of Sustainability, accessed on October 30, 2017, sustainability.mit.edu.

the magnitude of new renewables needed by 2030, but they point to the feasibility of cities taking large-scale action on decarbonization.

Forward-looking utilities and governments have proved they can facilitate massive expansions of renewables within a compressed time period. Orsted, for example, has transformed its energy business as part of Denmark's national push to reach 100 percent renewable electricity and heating by 2035 and is already on track to achieve a 72 percent renewable grid mix for electricity by 2020.[15] These examples can serve as a template for city–utility collaborations to accelerate grid decarbonization. Cities will need to work proactively with utilities on their decarbonization and electrification road maps to ensure these objectives are incorporated into broader system planning. For example, utilities often develop integrated resource plans on multiyear cycles, creating lag time between a utility's investment decisions and a renewable asset coming online. Open lines of communication also help utilities verify that critical investments in the grid, such as transmission and storage, are sufficient to avoid costly curtailment scenarios (where renewable generation assets go idle due to lack of grid capacity). As property owners shift to electric technologies, utilities, regulators, and cities can also work together to shape new demand profiles. For example, cities and regulators can collaborate to define time-based pricing for EV charging as an incentive to EV owners to help smooth, rather than exacerbate, existing peaks in electricity demand.

How cities differ

A city's strategy in pursuing electricity grid decarbonization will depend primarily on two factors: the local geography and the city's existing infrastructure and regulatory context.

Renewable resource characteristics. The natural environment in and around a city shapes its utility's strategy for renewables: how much solar, wind, and other renewable resources are available to build the balanced mix needed for grid stability; whether it is most economical to build power plant-scale projects in more remote areas or smaller installations close to or within the city; and whether the risk of flooding, storms, or other natural disasters warrants an emphasis on decentralized systems. Regional variations in the cost and availability of renewable energy solutions also factor into the feasibility of different approaches, including labor costs and experience with designing, developing, and operating different types of renewable assets.

Existing infrastructure and regulatory structure. The starting point of utility assets and energy policy matters: how much transmission capacity is already in place (or planned) to connect the city with new centralized renewables; whether the right pricing structures and grid capabilities can support high levels of distributed renewables; whether renewables could help avoid construction of new coal-, oil-, or gas-fired plants, or if the utility has already invested recently in new fossil-based generation; and how the current mix of renewables within existing power generation assets affects decisions in the future.

15 Peter Fairley, "Big customers demand 100 percent renewables—and utilities look set to deliver," *IEEE Spectrum*, August 24, 2017, spectrum.ieee.org.

Cities will need to work proactively with utilities on their decarbonization and electrification road maps to ensure these objectives are incorporated into broader system planning.

Where state or national regulations provide stable, sustainable pricing schemes for distributed renewables such as solar PV or enable cooperative ownership of centralized renewables, cities can do more to accelerate investment from companies and homeowners. Smart policy design for community-scale renewables—such as enabling developers to sell power above wholesale prices to facilitate an attractive rate of return where there is an additional value of solar to the network—can help cities capture both the scale advantages of centralized generation and the close-to-the-consumer advantages of on-site generation.

Illustrative 2030 road maps by city context

The following examples illustrate two ends of the spectrum based on a city's specific context.

A Small, High-Income, Innovator City's geography provides for a cloudy climate (not as good for solar) but abundant wind and hydro resources outside city limits. It focuses on accelerating centralized generation, working with its utility and raising capital through both public and private sources to finance enough wind capacity to decarbonize its grid by an additional 30 percentage points. Even with a challenging 2030 target of reducing per capita emissions to half of 2015 levels, this city achieves more than 50 percent of its target through grid decarbonization alone. Total investment needed through 2030 is around $600 per capita and $130 per metric ton of CO_2 equivalent, and the positive net present value (NPV) accrues to investors in energy savings and to the city's utility in avoided infrastructure investments.

A Low-Income Mega City has abundant solar resources thanks to its sunny geography. Its utility is willing to partner with the city to decarbonize the grid, as it sees an opportunity to grow more quickly and at lower cost compared with building fossil fuel plants. This city focuses on accelerating distributed solar and on-site electricity storage, working with the utility to finance installations on available land and eligible rooftops in the city, along with the necessary grid upgrades and investments in other low-carbon generation to balance the overall system. These measures enable the city to meet 70 percent of its building electricity needs with a mix of distributed and centralized renewables and achieve about 40 percent of its total emissions target for 2030, holding absolute emissions steady even as the city's population and standard of living grow. Total investment needed through 2030 is approximately $280 per capita and $30 per metric ton of CO_2 equivalent, and the positive net present value (NPV) accrues to a variety of stakeholders, including renewables developers and ratepayers.

CHAPTER 2.2

Optimizing energy efficiency in buildings

With millions of space heating systems, air conditioners, hot water, lights, appliances, and equipment, buildings are the biggest consumers of energy in most cities—and the biggest emitters of carbon. In particular, heating and cooling accounts for 35 to 60 percent of energy use in buildings around the world and generates, on average, nearly 40 percent of urban emissions. Cities can significantly reduce their carbon emissions by addressing not only the efficiency of appliances and equipment in buildings but also the efficiency of commercial and residential buildings themselves, including both high-rise and low-rise structures. Across all opportunities, cities will benefit from improving the availability of building energy data as a key enabling action to well-informed code or equipment changes. Our analysis indicates that many cities can reduce about 20 to 55 percent of the total gap in their emissions abatement targets by improving how buildings consume energy, not including additional opportunities in appliances.

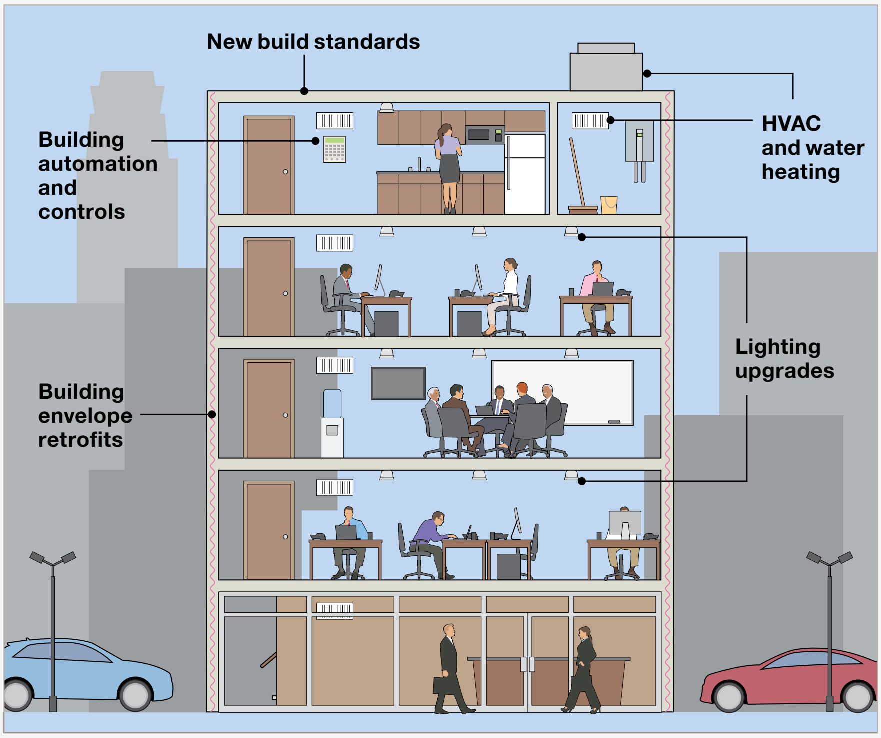
Focused acceleration of energy efficiency in municipal, commercial, and residential buildings would require significant up-front investments: around $20 to $100 per metric ton of CO_2 equivalent, translating to tens of billions of dollars in capital required through 2030 for a single city. But it also makes economic sense: packaged together, investments in more energy efficient buildings can generally be recouped through energy savings in 5 to 15 years for most cities, while continuing to reduce energy costs—as well as providing more resilient, comfortable spaces to live, work, and play—for city residents through 2050 and beyond.

The opportunities

For almost all cities, advancements in building design, systems, and technology offer several opportunities to reduce energy usage and emissions: higher standards for new builds, building envelope retrofits, lower-carbon technologies for heating and cooling, LEDs for more efficient lighting, and automation and controls for better energy performance (Exhibit 6). All opportunities provide positive NPV (discounted energy savings over the lifetime of the investment exceed up-front cost), especially when they are bundled together to take advantage of synergistic effects. In some specific cases, district-scale heating and cooling can be advantageous; these conditions are discussed in the section on how cities differ.

Raise energy efficiency standards for new builds. For any city, ensuring that new construction adheres to energy efficient design principles is one of the simplest ways to reduce emissions over the long term. Each new building constructed to high standards is one that won't need to undergo a potentially expensive and disruptive retrofit later to meet emissions reduction requirements. Many cities are already adopting higher-efficiency (or lower-emissions) standards for new buildings, often based on an existing rating or certification system. Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), and Passive House are a few of the better-known systems. Design principles considered in these

Exhibit 6



New build standards
Ultra high-efficiency standards for new construction; may include energy performance requirements or use of specific materials and technologies

Building envelope retrofits
Upgrade of walls, roof, windows, and doors (eg, cool roofs, high-efficiency windows, wall insulation)

HVAC and water heating
Upgrade of space heating, air conditioning, and water heating systems (eg, electric heat pumps, high-efficiency AC, solar water heating)

Lighting upgrades
Upgrade of incandescent and fluorescent bulbs to LEDs

Building automation and controls
Systems to optimize and monitor energy use (eg, lighting sensors, smart thermostats)

Illustration by Vic Kulihin

programs include airtightness, spatial orientation, and the use of materials that optimize natural solar heating in winter and maximize shading in summer (as well as use of natural light), and other features that minimize overall building energy requirements. Some cities have also opted to require specific types of energy efficient heating, ventilation, and air-conditioning (HVAC) systems, such as radiant heat rather than central forced-air systems; others have set energy performance and reporting requirements that encourage the adoption of state-of-the-art systems. Urban planning and zoning requirements can also promote higher-density development, which over time can decrease building energy demand by as much or more than efficiency improvements alone.[16]

In our analysis, we assume ultra high-efficiency building standards would be applied to 50 to 100 percent of new buildings in any given year for most city types and would achieve 50 to 70 percent lower energy use for those buildings by 2030 compared with the average existing stock. These energy savings are relatively conservative, as ultra high-

16 Michail Fragkias, Burak Güneralp, Mukesh Gupta, et. al., "Global scenarios of urban density and its impacts on building energy use through 2050," *PNAS*, August 22, 2017, Volume 114, Number 34, pnas.org.

For existing building stock, renovating the envelope—the roof, outer walls, windows, and doors that form a building's enclosed space—can reduce building heating and cooling demand by up to 40 percent.

efficiency building design has been shown to reduce heating and cooling demand by up to 90 percent and overall energy use by up to 75 percent.[17] Some cities have already applied such standards to an even larger share of new builds: in 2011, after several years of financing demonstration projects and building the market, the City of Brussels passed a requirement for all new buildings to be built to the Passive House standard, as well as any retrofits upgrading more than three-fourths of a building.[18]

Brussels has also demonstrated that the up-front cost of building to Passive House standards can be comparable to lower-efficiency construction: average cost for residential buildings is $1,758 per square meter compared with $1,746 for traditional construction, and Passive House has proved cheaper than traditional methods for commercial buildings. For our analysis, we assume a more conservative 10 percent cost premium based on previous McKinsey research.[19] As the costs of green construction materials fall, this up-front cost will also decline. However, cost is still a challenge for real estate developers that operate in a highly competitive, fragmented industry with very narrow margins and where it is hard to pass on additional costs.

Accelerate retrofits of existing building envelopes. For existing building stock, renovating the envelope—the roof, outer walls, windows, and doors that form a building's enclosed space—can reduce building heating and cooling demand by about 40 percent and enable buildings to use natural ventilation or install smaller HVAC systems or avoid heating and cooling altogether depending on the ambient environment. Eliminating or installing smaller air-conditioning systems could also significantly reduce the emission of hydrofluorocarbons (HFCs), powerful greenhouse gases from cooling systems. A full retrofit includes cooler roofs (which also reduce ambient temperatures in surrounding areas), improved wall insulation, better airtightness, and high-efficiency windows. In addition to saving on energy costs, retrofits also enhance urban resilience by mitigating extreme temperature risks to people and property in the event of power disruption during natural disasters and brownouts. Cities such as San Francisco and Toronto have created specific programs to enable lower-income communities to retrofit homes, such as in affordable housing and older apartment buildings, improving safety and reducing health hazards such as indoor condensation and mold in the process.[20]

17 "What is passive house?" New York Passive House, nypassivehouse.org.

18 Lenny Antonelli, "How Brussels went passive," *Passive House Plus*, October 26, 2016, passivehouseplus.ie.

19 Shannon Bouton, David Newsome, and Jonathan Woetzel, "Building the cities of the future with green districts," *McKinsey on Sustainability & Resource Productivity*, 2015, Volume 3, pp. 49–55, McKinsey.com.

20 "Cities100: Toronto—Apartment retrofits prioritize resident well-being," *Cities100*, November 15, 2016, c40.org; "Cities100: San Francisco—Equitable retrofits lower energy bills," *Cities100*, November 15, 2016, c40.org.

Full building assessments can reveal the costs and benefits of building envelope interventions. Where the heating and cooling demands may not justify a full envelope retrofit, simpler actions such as replacing windows and switching to cool or green roofs can achieve much of the potential energy savings potential while providing better financial returns. Cool roofs have been shown to decrease air conditioning load by about 10 percent, and high-efficiency windows can improve building energy performance by 20 percent.[21] Since windows and roofs are replaced or repaired more frequently than whole buildings are renovated, the faster turnover cycle enables these "mini-retrofits" to achieve significant energy savings for cities. Retrofits of building envelopes are usually combined with other measures such as lighting and HVAC.

Our analysis assumes that retrofitting envelopes alone could reduce heating and cooling energy demand by around 40 percent where demand is reasonably high (comparable to US Department of Energy findings) and that cities could address from 80 to 90 percent of their building stock by 2030, as several cities in Europe are on track to do.

Upgrade HVAC and water heating systems to low-carbon technologies. In cities with significant heating and cooling demands and where district-scale solutions are not appropriate, another major opportunity to reduce buildings emissions is to accelerate the adoption of high-efficiency and renewable systems, such as electric heat pumps, high-efficiency air-conditioning systems, and electric- or solar-based water heating systems. Since most heating and cooling equipment stays in operation for 10 to 20 years or longer, upgrading at the time of replacement can also lock in future emissions savings beyond the 2030 time frame. In the short term, shifting low-efficiency oil or natural gas heating systems to the highest-efficiency models can contribute up to 10 percent of a city's 2030 emissions target and offers a positive NPV today. Such technology is already mandatory for new HVAC systems in some markets such as the European Union.

In warm or temperate climates, using rooftop space for solar water heating can be a relatively low-tech, low-cost solution for reducing building emissions. In China, where some cities have reached nearly universal adoption on suitable rooftops, the cost to install a residential solar water heater can be as low as $200–300. While this cost is still higher than an electric or gas water heater, homeowners can achieve payback periods of around three years through savings on electricity or fuel costs when replacing a nonsolar-based system.[22]

In our analysis, we assume focused acceleration could achieve upgrade rates comparable with the levels that leading cities are already seeing for different HVAC and water heating technologies. In Scandinavian cities today, for example, electric heat pumps account for 55 percent of all sales of building heating systems;[23] Austria has committed to installing

21 "Cool roofing information for home and building owners," Cool Roof Rating Council, accessed November 6, 2017, coolroofs.org; *Technology roadmap: Energy efficient building envelopes*, International Energy Agency, 2013, iea.org; "Benefits: Energy & cost savings," Efficient Windows Collaborative, accessed November 6, 2017, efficientwindows.org; "How much can you really save with energy efficient improvements?" Energy.gov, October 7, 2016, energy.gov.

22 "Carrots and sticks boost renewables," WWF Global, March 1, 2012, wwf.panda.org; Umair Irfan, Kandy Wong, and E&E reporters, "Solar water heaters bloom on China's rooftops but not in the U.S.," *E&E News*, July 2, 2013, eenews.net.

23 Calculated based on 20 year upgrade cycle and 26–28 sales per 1,000 households, based on source: Thomas Nowak European Heat Pump Association, European Heat Pump Summit 2015.

three million square meters of solar thermal by 2030, or 2.2 square meters per capita, creating significant job opportunities in the local economy.[24]

Shift lighting to LEDs. Since renovations interrupt normal building operation, projects that address heating and cooling efficiency are often combined with other emissions reduction measures, which improves the overall business case and payback time for these investments.

Lighting accounts for 10 to 20 percent of energy consumption in buildings, with a slightly larger percentage in commercial buildings than residential ones.[25] Switching to LED lights that last longer and produce more light per watt can reduce electricity demand for lighting by 30 percent compared with fluorescent lights and by 80 percent compared with incandescent light bulbs. LED costs have improved considerably over the past decade, and each new bulb (lamp) can pay back its up-front cost in electricity savings in less than two years when replacing incandescent bulbs.[26] In addition to the opportunity inside of buildings, cities can also reduce emissions in the outdoor built environment by converting streetlights to LEDs. Amman, for instance, is replacing 119,000 streetlights with LEDs and expects to reduce streetlighting costs by half as a result.[27] Los Angeles has put 114,000 LED streetlights in place to date and reduced its annual costs for electricity and maintenance by $7.5 million and $2.5 million, respectively—all while improving lighting quality.[28] In our analysis, we assume lighting upgrades can achieve similar results to our prior work with individual cities: an average of 50 percent lighting efficiency gain, with 85 percent of indoor lighting and 100 percent of streetlights using LEDs by 2030.

Expand use of building automation and controls. Even with the best technology, building energy performance tends to drift over time, especially as occupants leave lights or appliances on or overcorrect on heating and cooling adjustments. Automation and control systems such as adaptive thermostats, lighting sensors, and plug load monitors help ensure buildings are comfortable and functional for occupants while still optimizing energy efficiency. Building automation systems can also be integrated with on-site renewable energy generation and local utility demand management programs—for instance, by running appliances such as dishwashers and tumble dryers at times when overall energy demand is lower to further improve the emissions profile of buildings. In our analysis, again based on our prior work with individual cities, we assume automation and controls can achieve 2 to 5 percent reduction in building energy use and that cities can achieve installation in 15 to 40 percent of buildings by 2030. These opportunities address the largest sources of greenhouse gas emissions from buildings in most cities. Additional opportunities may be important for a minority of cities, such as shifting from fuel-based to electric or low-carbon cooking, improving the efficiency of electric appliances, and reducing emissions from the industrial sector (see sidebar, "Industrial energy efficiency").

24 Bettina Auinger, Brigitte Branstätter, Gerhard Dell, et al., *Carrots, sticks, and tambourines: How Upper Austria became the world's leading solar thermal market*, O.Ö. Energiesparverband, December 2010, energiesparverband.at.

25 *Lighting Efficiency: Climate TechBook*, Pew Center on Global Climate Change, April 2011, c2es.org.

26 Based on McKinsey analysis.

27 "GAM signs deal to replace 119,000 street lights with LED unites," *Jordan Times*, February 11, 2017, jordantimes.com.

28 Justin Gerdes, "Los Angeles saves millions with LED street light deployment," *Forbes*, January 25, 2013, forbes.com.

Industrial energy efficiency

For cities with a large industrial sector that contributes heavily to carbon emissions, improving process and energy efficiency in industrial buildings and facilities is critical. McKinsey research shows that industrial operational improvements can reduce energy consumption by 10 to 20 percent. Further, investment in energy efficiency technologies can contribute an additional 30 to 40 percent and save hundreds of billions of dollars a year in energy costs.[1] Most industries currently have at least one commercially viable energy efficiency solution that could reduce energy demand by at least 15 percent on its own.[2] Operational improvements can also make more efficient use of energy, often with no additional capital expenditure. For example, by creating more predictable electricity load profiles with fewer spikes in energy use, plants can avoid costly peak demand charges and earn credits by participating in demand response programs with the utility.

1 Nicole Roettmer, Erik Schaefer, and Ken Somers, "Capturing the lean energy-efficiency opportunity in industrial and manufacturing operations," *Energy efficiency: A compelling global resource*, 2010, McKinsey.com.

2 Harsh Choudhry, Mads Lauritzen, Ken Somers, and Joris Van Niel, "Greening the future: New technologies that could transform how industry uses energy," August 2015, McKinsey.com.

Breaking down barriers: How acceleration is possible

Many cities have been working to improve building energy efficiency for some years, and while a few leaders have begun to unlock the true scale of the opportunities available, much more remains to be done and quickly. Recent innovations could help capture this opportunity, especially if cities work together and share the lessons learned from their efforts. We believe the key to capturing emissions savings in buildings is through focused, large-scale initiatives with committed engagement from all necessary stakeholders. Our analysis of the emissions reduction potential in buildings is based on renovation and upgrade rates that leading cities are on track to achieve by 2030 through such coordinated, at-scale programs.

Demonstrate leadership. Cities can lead the way on building efficiency by proactively retrofitting their own buildings; they generally have a high degree of control over their own municipal buildings and can move forward quickly with energy efficiency retrofits and energy consumption reduction measures, demonstrating leadership and saving public money in the process. Cities such as Vancouver are already requiring net zero carbon standards for all new municipal buildings.[29] These kinds of initiatives create new local jobs, better health for building residents and users, and lower energy bills as well as reduced emissions.[30] Meanwhile, Bogotá has begun benchmarking emissions from its public hospital network, which has already resulted in several pilot projects such as solar water-heating installations that have decreased energy use, despite a significant increase in hospital services provided.[31]

29 Johanna Partin and Michael Shank, "Because national governments won't, cities are pushing zero-energy buildings," *Fast Company*, March 25, 2016, fastcompany.com.

30 *Pembina institute*, "Vancouver's green buildings policy is good news for homeowners and renters," blog entry by Lee Loftus and Karen Tam Wu, May 1, 2017, pembina.org/blog.

31 "Cities100: Bogotá—Hospital program shrinks CO_2, improves patient experience," *Cities100*, November 15, 2016, c40.org.

Bypass natural renovation cycles. The longevity of building stock, which tends to come due for major renovation every 30 to 50 years, is one of the main challenges in accelerating improvements. This time frame makes tightening new build standards one of the biggest emissions reduction opportunities across all cities, even when applied only to a subset of new construction (common in many cities today), and even with conservative estimates for the energy savings from ultra high-efficiency standards. To tackle existing building stock, cities have taken steps to bypass natural renovation cycles by tying upgrade requirements to more frequent triggers, such as changes in ownership. For example, New York requires requires owners of large buildings to complete periodic energy audits and retro-commissioning of equipment, and provides assistance through its Retrofit Accelerator program for owners who want to pursue deeper retrofits as a result.[32] New York also recently announced plans to introduce a fossil fuel cap for high-rise buildings to accelerate envelope retrofits and HVAC system upgrades. In Tokyo, a similar cap-and-trade program for large buildings has already reduced emissions by 22 percent in its first phase.[33] In Shenzhen, 635 companies and 197 large infrastructure projects are participating in an emissions trading scheme that has achieved a 12.6 percent reduction in emissions even as economic activity has grown.[34]

Another challenge of building upgrades is that retrofit projects are disruptive for occupants, who often need to relocate until the project is complete, resulting in loss of income for building owners. However, innovations in rapid envelope retrofits, such as the Energiesprong model in the Netherlands, enables prefabricated exteriors that can shorten project lengths to weeks compared with the normal time frame of months. Such methods minimize disruption to occupants and dramatically improve the business case for building owners.[35] This technology and operations-based approach can help put cities on track to renovate 20 to 30 percent of low-rise buildings by 2030.

Use novel business and financing models to improve the business case. A common obstacle to energy efficiency retrofits is financial: building retrofits involve significant up-front costs, long payback periods for upgrades (as much as 20 to 25 years for envelope improvement, and significantly longer in difficult cases), and overcoming the "split incentive" problem (whereby developers or owners invest in energy efficiency improvements, but building occupants reap the energy savings on their utility bills). Unlocking private capital, working with investors such as pension funds and real estate management companies that have long-term financial goals, and shortening payback periods are key approaches to creating buildings that are more energy efficient, cheaper to run, and better to live, work, and play in. Bundling multiple improvements together can reduce customer acquisition costs and enable deep retrofits with reasonable paybacks. For example, a building renovation that includes retrofitting the envelope along with upgrades to HVAC,

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32 "LL87: Energy audits & retro-commissioning," NYC Mayor's Office of Sustainability, accessed November 6, 2017, nyc.gov.

33 "Tokyo's urban cap-and-trade scheme delivers substantial carbon reductions," *C40 Cities*, November 17, 2015, c40.org.

34 "Cities100: Shenzhen—Carbon trading decouples growth from climate impact," *Cities100*, October 30, 2015, c40.org.

35 Arno Schmickler, "Energiesprong—making net-zero energy housing a reality," National Energy Foundation, November 4, 2016, nef.org.uk; "What are net zero energy refurbishments?" Transition Zero, accessed November 6, 2017, transition-zero.eu.


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water heating, lighting, and automation systems can pay back investments through energy savings within five to ten years. Innovative financing models can also overcome the split incentive issue. One example is performance-based energy contracts, where a third party manages the installation of low-carbon solutions and then continually optimizes the building's systems to ensure full benefits are realized in return for a share of the energy savings. The Municipality of Paris has had success in retrofitting 100 schools in an initial phase under an environmental performance criteria model and is now rolling out the model more widely.[36]

Push for higher efficiency and phase out of fossil fuel HVAC. Where fossil fuel heating is prevalent in existing buildings, cities have achieved accelerated emissions reductions through a two-pronged approach: requiring high-efficiency fossil fuel systems in the short term and putting in place longer-term measures to phase them out and replace with electric or renewable technology. Scandinavian cities require that all fossil fuel-based systems use high-efficiency technology, such as condensing boilers and tankless water heating, while simultaneously promote even lower-carbon alternatives, resulting in about 35 percent of buildings using electric heat pumps as of 2017.[37] Performance-based emissions standards such as those in New York and Tokyo help increase the adoption of low-carbon HVAC and water heating without dictating the use of specific technology. New York's performance mandates will also result in 40 fewer premature deaths and 100 fewer emergency room visits per year through improved air quality, and by 2030 will have created 17,000 new construction-related jobs.[38] Given the long lifetimes of HVAC and water heating equipment in buildings—often 10 to 20 years or more—it's essential that cities proactively phase out fossil fuel-based technologies by 2030. Cities can help build the market and lower the cost of replacement technologies through efforts such as incubator and pilot programs that provide proof points to the broader market.

36 "Paris school retrofit project tackles energy efficiency," *C40 Cities*, September 18, 2014, c40.org.

37 Thomas Nowak European Heat Pump Association, European Heat Pump Summit 2015.

38 *1.5°C Aligning New York City with the Paris Climate Agreement*, C40 Cities, September 2017, nyc.gov.

How cities differ

The emissions reduction potential of different buildings solutions in a given city depends largely on three factors: climate, existing building stock, and growth.

Climate. It's no surprise that climate dictates a city's overall heating and cooling requirements. For example, cold climates have a large differential between outdoor and comfortable indoor temperatures—so building envelopes become especially important for preventing heat loss. Where cities experience long winters, improving building envelope performance alone can achieve around 5 to 10 percent of their 2030 emissions abatement targets. In hot climates where natural ventilation is insufficient for cooling, high-efficiency air-conditioning becomes the biggest opportunity, especially as climate change leads to more frequent heat waves and more days when cooling is required. In mild climates, buildings can often be designed for natural ventilation, thereby avoiding the use of air-conditioning altogether.

Existing building stock. The more inefficient buildings currently are (for example, due to inadequate insulation and sealing, older heating and cooling technology, or low or poorly calibrated automation), the greater the potential for energy savings from efficiency upgrades and the better the business case for low-carbon investments. For example, older suburban cities, which are dominated by single-family homes built to low-efficiency standards, have higher per capita emissions than denser cities with more efficient high-rises.

Income and population growth. For cities expecting rapid growth in income or population—and the flurry of building construction and increased energy use that accompany it—high-efficiency standards for buildings are imperative for curbing emissions. Residents tend to demand more floor space per capita and controlled indoor climates as their incomes rise, and rapid construction has often led to shoddy design and buildings that perform poorly on energy efficiency. Strong building codes and enforcement, proactive energy efficiency improvements, and smart urban planning and development are essential to ensuring that rising prosperity and population don't lead to runaway total energy use.

In some circumstances, fast-growing cities can use district heating and cooling (larger-scale systems built to serve multiple buildings) to provide low-carbon heating and cooling alongside rapid building construction. District systems are most economical in places with high demand for both heating and cooling, free low-carbon resources

Strong building codes and enforcement, proactive energy efficiency improvements, and smart urban planning and development are essential to ensuring that rising prosperity and population don't lead to runaway total energy use.

such as industrial-waste heat and lakes or oceans for cooling, and a high volume of development within the system's feasible service area. Tokyo's Sky Tree Town uses a combination of heat pumps and water tanks in its district system, reducing energy use by 44 percent and greenhouse gas emissions by 50 percent compared with individual systems.[39] Cities that already have district energy systems in place may find expanding coverage to additional new buildings to be especially cost-effective. Toronto's centralized steam-heating system, built in the 1970s, was expanded in 2004 to add cooling capability using water from Lake Ontario. For eligible buildings in Toronto, connecting to the district cooling system costs 10 to 15 percent less in operating costs than conventional chillers.[40]

39 *JFS*, "District heating and cooling of Tokyo sky tree area largely reduces energy use, CO_2 emissions," October 29, 2013, japanfs.org.

40 Gail el Baroudi, "An answer for the heat? Cool clear water," *The Globe and Mail*, July 18, 2006, beta.theglobeandmail.com.

Illustrative 2030 road maps by city context

The following examples illustrate two ends of the spectrum based on a city's specific context.

A Small, High-Income, Innovator City, with a cold climate, slow growth, and often old and historical buildings in the city center, focuses on accelerating two opportunities: retrofits of existing building envelopes and upgrading to low-carbon heating systems. It establishes a "retrofit incubator" model to support pilot installations and rapidly scale up innovations to automate and standardize the envelope retrofit process, enabling it to improve 95 percent of its building stock by 2030. At the same time, the city works with the national government to require minimum emissions performance in HVAC and water heating systems and build the market for new solutions—with an eye toward becoming a regional or global leader in advanced building technologies. Electric heat pumps grow to account for half of all space heating systems, and 100 percent of water heating systems are either electric or solar by 2030. The resulting emissions reductions achieve about 3 percent of the city's total 2030 emissions reduction target. The total incremental investment required through 2030 is approximately $11 billion, or about $4,000 per capita and $100 per metric ton of CO_2 equivalent, with positive NPV and aggregate payback of six to eight years.

A Low-Income Mega City, with a hot climate and fast growth, focuses primarily on establishing Passive House standards for new builds and renovations, including new efficiency requirements for air-conditioning systems, and encouraging dense development for new builds. Half of new buildings from 2017 onward are 50 to 70 percent more efficient than existing buildings, and as the city grows, these structures come to represent a full third of total building stock, contributing about 22 percent of the total emissions reductions needed for the city's 2030 target. The total incremental investment required through 2030 is approximately $12 billion, or about $550 per capita and $20 per metric ton of CO_2 equivalent, with positive NPV and aggregate payback of five to nine years.

CHAPTER 2.3

Enabling next-generation mobility

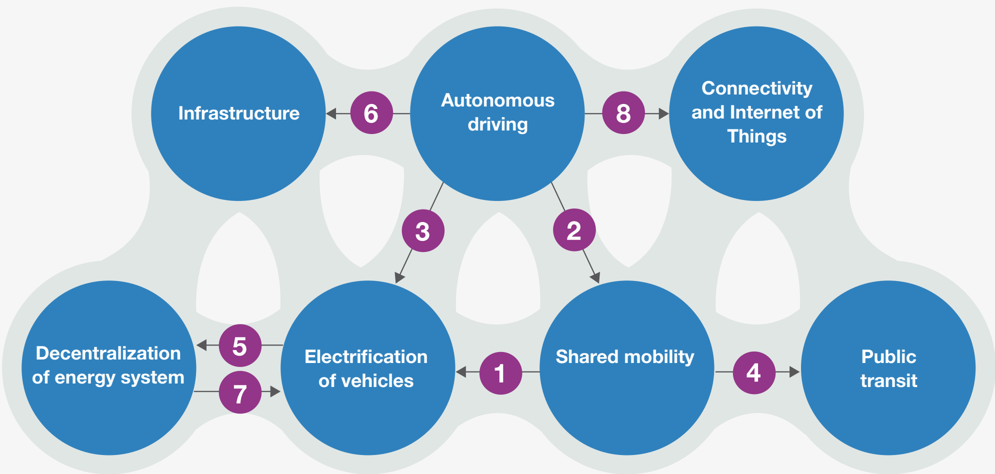
As cities grapple with the influx of people into urban centers, mobility of both people and goods has become one of the most pressing concerns for elected officials and policy makers. The current situation is already untenable in many cities, with local air pollution reaching dangerous levels for human health and traffic congestion costing as much as 8 percent of total city GDP in some urban centers.[41] Cities simply cannot afford to accept "business as usual" when it comes to transportation.

Fortunately, at the same time, multiple mutually reinforcing trends in mobility and land use planning are starting to transform the experience of getting around in cities. The transportation industry is already reorienting to this new reality: car manufacturers, oil and gas companies, utilities, and infrastructure providers alike assume that cars and trucks will be used in dramatically different ways in the future than they are today. Exhibit 7 shows how some of these trends will likely interact: for example, autonomous

41 *TheCityFix*, "Study: Rio de Janeiro and São Paulo lost USD 43 billion from traffic congestion in 2013," blog entry by Renato Lobo, July 31, 2014, thecityfix.com/blog; *The future economic and environmental costs of gridlock in 2030, Centre for Economics and Business Research*, July 2014, ibtta.org.

Exhibit 7

Key trends



Reinforcing effects

1. An update in shared mobility will accelerate electrification, as higher utilization favors the economics of electric vehicles.
2. Self-driving could merge shared mobility business models into a single proposition competitive with private car ownership and public transport.
3. Self-driving—private and shared—vehicles are likely to increase mobility consumption, in which case, electric vehicles offer lower total cost of ownership.
4. An update in shared mobility will affect public transit.
5. Electric vehicle production at scale would accelerate battery cost reductions, with multipe effects.
6. Self-driving electric vehicles will have different usage and hence requiring different requirements for charging infrastructure.
7. Increasing renewable power generation will make electric vehicles more attractive as a means to reduce the carbon intensity of the transport sector.
8. Self-driving vehicles might accelerate the uptake of IoT applications.

Source: Bloomberg New Energy Finance and Future of Mobility team analysis driving could accelerate the creation of new business models for low-cost shared mobility, which could complement public transit offerings.

To harness these trends and reduce emissions, cities will need to proactively shape the mobility landscape to ensure that a variety of affordable, attractive options are available to everyone. For many cities, opportunities in this action area can comprise 20 to 45 percent of emissions reductions needed by 2030, depending on city context. In the process, these efforts can transform the quality of life for residents by reducing time lost from congestion, alleviating local air pollution and associated health effects, and freeing up valuable city real estate.

The opportunities

Next-generation mobility encompasses not only the modes of transport that city residents use to get from one point to another but also the design and development of urban centers. Limiting emissions from the flow of commuters and goods throughout a city is a complex challenge, but one that can be addressed through four primary opportunities (Exhibit 8).

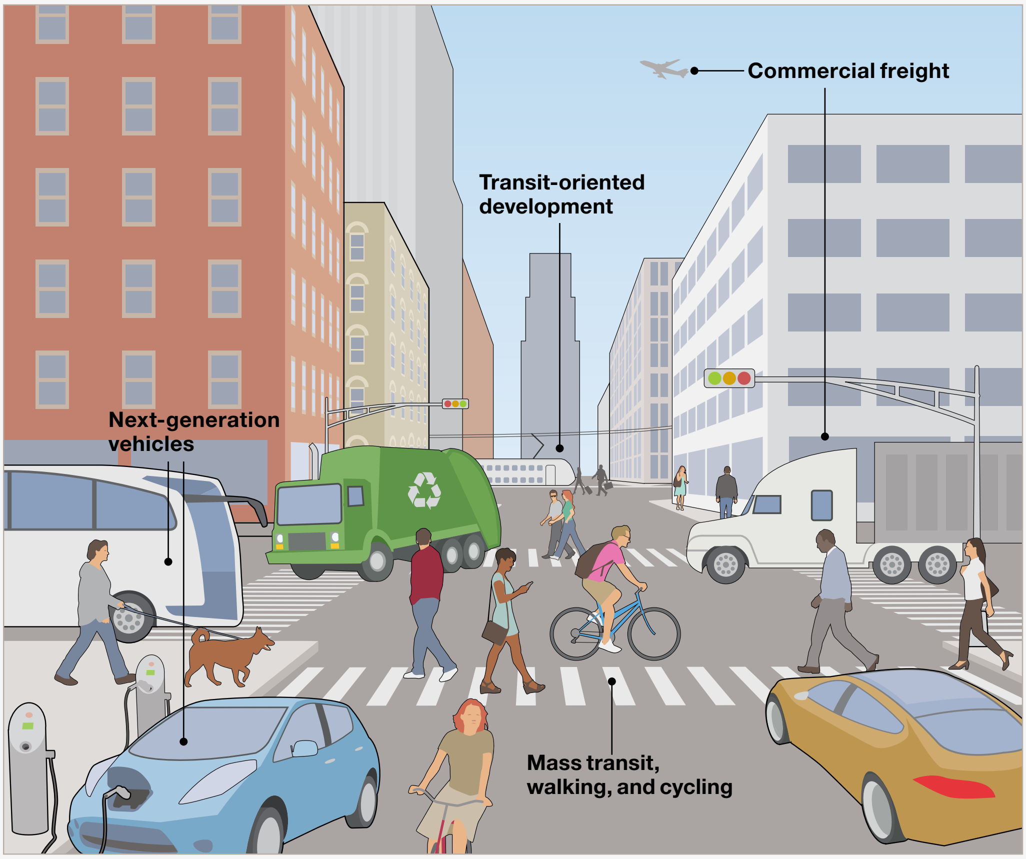
Accelerate transit-oriented development. Clean, connected, shared vehicles will open new possibilities for mobility within a city, especially in combination with improvements to transport infrastructure and the urban environment. Thoughtful urban planning and development can achieve a virtuous cycle for cities by locking in lower emissions as buildings, transport systems, and other infrastructure are constructed for greater efficiency, and higher population density makes a range of mobility solutions feasible. For example, denser development in the core of the city and near employment nodes can reduce average travel time, particularly when coupled with pedestrian and bicycle improvements and transit infrastructure investments. A critical mass of potential riders in an area improves the business case for systems such as mass transit, shared vehicles, and electric vehicle charging networks.

These developments can also be cost-effective for a city with the right financing structures in place. For example, the areas around Tokyo's railway stations boast dense, multiuse communities, making them models of financially successful transit-oriented development. Metro operators are at the center of this development, and reap increased financial benefits by diversifying into real estate, retail, and numerous other businesses that transform metro stations into "attraction centers" within the districts where they are located.[42] Similarly, the City of Johannesburg is investing in Corridors of Freedom, a transport-oriented development strategy to link mixed-use development nodes along transport arteries. This development approach is designed to not only reduce overall service costs for the city, but also bring citizens closer to jobs and services, increase access to affordable housing opportunities, and boost overall connectivity and opportunities for economic development.[43]

42 John Calimente, "Rail integrated communities in Tokyo," *Journal of Transport and Land Use*, 2012, Volume 5, Number 1, pp. 19–32, jtlu.org.

43 "Development planning, Joburg, my city, our future," updated on August 16, 2017, joburg.org.za; "TOD will improve quality of life," Johannesburg Development Agency: Building a better city, jda.org.za.

Exhibit 8



Transit-oriented development
Dense, mixed-use, walkable development with transit connectivity

Mass transit, walking, and cycling
Infrastructure to support greater use of alternatives to private vehicles (eg, protected cycling lanes, bus rapid transit)

Next-generation vehicles
Electric cars, trucks, buses, and other vehicles with connected, shared, and autonomous features

Commercial freight
Changes in operations and technologies to streamline commercial traffic (eg, night delivery, urban consolidation centers, parcel lockers)

Illustration by Vic Kulihin

Indeed, we have found densification through smart planning to be one of the biggest opportunities to reduce transportation emissions, especially in fast-growing cities. This is largely because increasing density tends to boost walking, cycling, and public transit ridership, particularly in areas that already have accessible public transit.[44] Based on this finding, our analysis shows that raising the average population density per square kilometer by 3 to 10 percent can can contribute 5 to 15 percent of emissions reductions needed by 2030. Beyond these shorter-term benefits, land use planning and dense development also lock in positive development patterns that reduce longer-term emissions, improve equitable access, and support economic development for decades to come.

44 *Land use impacts on transport: How land use factors affect travel behavior, Victoria Transportation Policy Institute*, July 2017, vtpi.org.

Encourage mass transit, walking, and cycling. To capture the full potential of emissions reduction, cities will need to ensure walking, cycling, and mass transit remain accessible and attractive options for moving around the city.

Improving mass transit coverage and experience can help attract passengers to lower-carbon forms of motorized transport such as buses and rail service, especially in cities with low rates of car ownership. Multiple factors influence people's decisions to take mass transit, including frequency, safety, reliability, cleanliness, and convenience of service. Cities can make targeted enhancements to mass transit, such as introducing BRT on main arteries, renovating major stations for improved security, or adding stations to increase access for underserved areas. For example, in 2002 Boston added four new stations to a train line, the Fairmount/Indigo Line, running between the central business district and the southern outskirts of the city, which is one of its poorest and most densely populated areas. This extension not only boosted mass transit ridership but also spurred revitalization of areas along the route, with community development corporations buying and rebuilding more than 1,500 housing units, developing 780,000 square feet of commercial space, and creating more than 1,300 jobs.[45] Similarly, the South African City of Tshwane introduced a dedicated BRT route featuring low-emissions buses to provide residents on the city's outskirts with faster, more reliable access to the city center. Aware that the route would replace existing informal minibus transit systems, the city offered financial compensation and a shareholder stake in the new BOC (bus operating company) to those displaced by the updates.[46] In Addis Ababa, where transport accounts for 47 percent of total emissions and the electricity grid is powered almost exclusively by renewables, a new light-rail system has more than doubled average transport speed in the city and created more than 1,100 jobs while also reducing local air pollution.[47]

Cities can encourage nonmotorized transport by making walking and cycling more attractive, particularly in dense, transit-oriented areas. Our analysis shows that enhancing walking and cycling infrastructure with features such as protected, spacious, conveniently located bike lanes and sidewalks can achieve an additional 5 to 15 percent of the 2030 emissions reduction target. These physically active modes of transportation have additional benefits: research shows that improving walkability by 5 percent can not only reduce vehicle mileage by approximately 6.5 percent but also contribute to better health for individuals.[48]

To further encourage mass transit, walking, and cycling, cities can introduce measures such as automated tolling, dynamic lane openings, reduced or dynamically priced parking in congested areas, and designate zones for nonmotorized transport. Where attractive alternatives to private cars exist for specific trips, these congestion management measures can serve to direct travelers to choose lower-carbon, higher-occupancy forms of mobility as well as reducing emissions from cars that sit idling in congestion. Stockholm introduced

45 Shannon Bouton, David Cis, Lenny Mendonca, Herbert Pohl, Jaana Remes, Henry Ritchie, and Jonathan Woetzel, *How to make a city great,* McKinsey Cities Special Initiative, 2013, McKinsey.com.

46 "Cities100: Tshwane—Creating a reliable alternative to informal transit," *Cities100*, October 30, 2015, c40.org.

47 "Cities100: Addis Ababa—Sub-Saharan Africa's first light-rail train," *Cities100*, November 15, 2016, c40.org.

48 William Bachman, Terry L. Conway, Lawrence D. Frank, et al., "Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality," *Journal of the American Planning Association*, March 2006, Volume 72, Number 1, pp. 75–87, researchgate.net.

To further encourage mass transit, walking, and cycling, cities can introduce measures such as automated tolling, dynamic lane openings, reduced or dynamically priced parking in congested areas, and designate zones for nonmotorized transport.

a congestion charge in 2006, and this measure (combined with extension of mass transit) has achieved a sustained 20 percent reduction in vehicle traffic.[49] London's congestion zone has reduced carbon emissions by 15 to 20 percent and fine particulates and nitrogen dioxide (NOx) by 10 percent.[50]

Like transit-oriented development, investments in infrastructure to encourage mass transit as well as walking and cycling generally require net capital expenditure by cities and other government agencies. However, these outlays are net positive from a broader economic perspective. Tolls and dynamically priced parking may generate revenues, as do mass transit fares and payments to bike-sharing services, and reduce stress on road infrastructure. Where the economics make sense, public–private partnerships can be used to finance these investments. Additional economic benefits, however, are harder to quantify as they accrue to city residents and businesses in the form of increased foot traffic in commercial retail areas, greater productivity from reduced traffic congestion and commute times, and improved quality of life that increases property values and attracts new businesses and residents to the city.

Enable next-generation vehicles. Four interrelated industry trends could help usher in an era of seamless low-carbon mobility: electrification of vehicles; shared mobility (for example, car-share fleets, e-hailing services, on-demand van and minibus transport, and freight load-pooling); autonomous (self-driving) vehicles (AVs); and wireless connectivity that enables communication between vehicles and with the broader transport infrastructure. These trends reinforce each other as they develop. For example, connected and autonomous technology could reduce the cost of shared mobility solutions such as e-hailing services, which could operate without drivers and dispatchers. Electric vehicles have lower total cost of ownership (TCO) than fossil fuel vehicles, making electrification especially attractive for shared mobility and autonomous delivery services. Meanwhile, connectivity between cars and infrastructure not only enables autonomy but also a whole suite of other solutions that can improve traffic flow, including real-time routing away from congestion and smart traffic lights. Alongside these newer technology trends, ever-increasing fuel economy in conventional internal-combustion vehicles will play a significant role, contributing around 10 to 25 percent of total emissions reductions needed by 2030. In all, acceleration of these trends could contribute 20 to 45 percent of total emissions reductions depending on city context.

49 Eric Jaffe, "A blueprint for beating traffic," CityLab, December 15, 2011, citylab.com

50 Ed Pike, *Congestion charging: Challenges and opportunities*, The International Council on Clean Transport, April 2010, theicct.org.

Until the grid is completely decarbonized, all motorized vehicles will contribute greenhouse gas emissions. However, for most cities EVs will have a lower emissions profile than comparable internal-combustion vehicles and offer the added benefit of reducing transport-related local air pollution (such as particulate matter and nitrogen oxide) and noise in city streets. As EVs become more widely available and competitive on TCO, cities can achieve electrification of up to 12 percent of the total vehicle park by 2030 and contribute up to 20 percent emissions reduction toward a 1.5°C trajectory by accelerating the electrification of private, commercial, and public transit vehicles.

As EV models become more widely available and affordable, they could achieve up to nearly 30 percent of new vehicle sales by 2030, though this uptake is unlikely to be uniform;[51] cities that want to achieve higher uptake will likely have to undertake broader efforts. Indeed, with city incentives, EVs could account for up to 50 percent of new vehicle sales in this time frame. In addition, McKinsey research indicates that other new mobility trends will also start to take hold by 2030: up to 10 percent of cars sold could be a shared vehicle, and up to 15 percent of new cars sold that year could be fully autonomous. Given the reinforcing character of the four mobility trends described above, significant growth in shared vehicles, AVs, and connectivity will likely lead to higher EV adoption rates. (See sidebar, "Autonomous vehicles.")

Buses are prime candidates for cities; managed fleets are particularly well suited for electrification since vehicles can be rotated offline to charge as needed and follow fixed routes so that charging station locations can be optimized. Cities with large bus fleets can achieve up to 1 to 3 percent of target emissions reduction by converting all buses to electric models by 2030.

51 Shannon Bouton, Eric, Hannon, Stefan Knupfer, Detlev Mohr, Timo Moeller, Jan Tijs Nijssen, Surya Ramkumar, Swarna Ramanathan, Christer Tryggestad, and Colin McKerracher, Itamar Orlandi, Michael Wilshire, *An Integrated Perspective on the Future of Mobility*, a joint report from McKinsey & Company and Bloomberg New Energy Finance, October 2016, McKinsey.com.

Autonomous vehicles

From an emissions perspective, the main potential benefit of fully autonomous technology beyond accelerating EV adoption will be improved traffic flows across the city. This "fleet effect" results from AVs that can quickly identify alternative routes for congested arteries, better manage acceleration and braking, drive faster and closer, and otherwise improve on human driving behavior. Based on announcements by major automakers, AVs will become commercially available starting after 2020; even with rapid adoption, AVs are unlikely to achieve the critical mass needed for a substantive fleet effect in cities before 2040. In the meantime, robust data collection from pilot programs of this nascent technology will be essential to understanding their potential impact on city traffic, the safety and productivity of residents, and the best strategies for shaping AV use to achieve the maximum benefit for residents and the climate.

Enable next-generation freight transport and delivery. Cities where logistics and deliveries are significant contributors to emissions can work with the private sector to decarbonize supply chains and transform commercial freight. While long-haul freight, which generally takes place outside of urban centers, is harder for cities to directly influence, they can work with logistics companies and businesses to implement strategies to dramatically reduce emissions from last-mile urban delivery. An integrated solution that incorporates elements such as night deliveries, parcel lockers, and electric delivery vehicles can offset 60 to 70 percent of the emissions contributions of both business-to-business and business-to-consumer deliveries.[52] Businesses are often more than willing to collaborate. In Hamburg, for instance, UPS worked with city officials to support the goal of no motorized vehicles in the city core. The logistics provider even designed an electrically assisted tricycle to take packages to and from a central parcel trailer. UPS estimates this solution has reduced emissions by more than 70 metric tons of CO_2 equivalent in the city.[53]

Breaking down barriers: How acceleration is possible

Passenger vehicles tend to represent the largest opportunity in most cities, as they are generally the dominant type of vehicle on the road; in the United States, they are responsible for around 70 percent of total road transport emissions.[54] Shared vehicles in particular (taxis and cars used for e-hailing services such as Lyft and Uber) have particularly high potential for accelerating electrification and reducing emissions. These vehicles have higher utilization and, as a result, shorter life cycles—a fact that already contributes to a tendency for shared vehicles to be newer and more fuel-efficient models. Electrification is encouraged by the lower operating and maintenance costs compared with traditional internal-combustion engines, leading to a lower lifetime TCO. Through a combination of electrification and higher fuel efficiency, our analysis indicates that shared vehicles as a group will become up to 25 percent more energy efficient than personal vehicles by 2030.

Cities can further boost EV adoption through preferential treatment such as designated driving lanes or parking, subsidies, zero-emissions zones, and easy-to-find, convenient charging. For example, creating low-emission zones, in which high-emission vehicles are excluded, could help encourage the shift to lower-emission vehicles. More than 220 cities and towns in 14 countries around Europe have either implemented or plan to implement such zones.[55] Another important factor in consumer decisions to purchase EVs is charging infrastructure. Cities can help promote awareness of the existing charging network to promote EV adoption, either in place of, or as a complement to, other measures such as direct subsidies or incentives such as free premium parking.

52 Shannon Bouton, Eric Hannon, Linda Haydamous, Bernd Heid, Stefan Knupfer, Tomas Naucler, Florian Neuhaus, Jan Tijs Nijssen, and Swarna Ramanathan, *An integrated perspective on the future of mobility part II: Transforming urban delivery*, McKinsey Center for Business and Environment, September 2017, McKinsey.com.

53 “Sustainability solutions,” UPS, ups.com.

54 “Fast facts on transportation greenhouse gas emissions,” *Green Vehicle Guide*, United States Environmental Protection Agency, epa.gov.

55 “Overview of low emissions zones,” *Urban access regulations in Europe*, accessed October 31, 2017, urbanaccessregulations.eu.

New mobility technologies and business models can also be designed to ensure that measures intended to reduce congestion and emissions do not have a disproportionate impact on low-income citizens. For example, Los Angeles is launching an EV car-sharing fleet in low-income communities with poor transit access to help improve environmental conditions and economic prospects in these communities.[56] Similarly, e-hailing services can be subsidized to provide first- and last-mile coverage for underserved communities in order to ensure access to transit hubs.[57]

As shared mobility and autonomy become more prevalent, cities can proactively manage and limit the net emissions impact of these vehicles by shaping customer usage and behavior. For example, AVs could be sent on zero-occupancy errands or in search of parking, and shared vehicles could spend much of their time circulating empty while waiting to be matched with passengers. Cities can collaborate with mobility providers to encourage high-occupancy solutions such as supporting on-demand van and minibus services, aggregating pickup and drop-off points (such as transit hubs), and raising occupancy requirements for high-occupancy-vehicle (HOV) lanes and zones.

How cities differ

Cities looking to design a clean transport model, mitigate carbon emissions, and meet mobility needs would do well to consider per capita income and population density. Even more than geographic region, these characteristics tend to be the primary factors that determine the potential for next-generation urban mobility.

Per capita income. Cities with lower per capita income tend to have faster-growing populations and more ongoing rapid urbanization than higher-income cities, making solutions that address congestion and air pollution (such as ride-sharing and electrification) particularly

56 "Cities100: Los Angeles—Electric car-sharing in low-income communities," *Cities100*, November 15, 2016, c40.org.

57 Shannon Bouton, D. Canales, L. Da Silva, et al., *Connected urban growth: Public-private collaborations for transforming urban mobility*. Coalition for Urban Transitions, New Climate Economy, 2017, newclimateeconomy.net.

attractive. Cities with higher per capita income, where labor costs tend to be higher and infrastructure more consistent, will likely see faster penetration of advanced connected technology such as electrification and autonomy. Income levels will also likely shape the mass transit options that a city pursues. For example, a BRT system can achieve many of the same goals as a light-rail system at lower cost, given its use of buses and existing road infrastructure, and has been embraced more widely by developing cities.

Population density. In densely populated cities, air pollution, congestion and scarcity of parking tend to strengthen the case for mass transit, nonmotorized transport, and shared electric mobility as well as provide critical mass for rapid adoption of these modes. On the other end of the spectrum, low-density suburban cities could continue to see private cars as the central element of mobility. For these cities, electric vehicles and autonomy could help offset the emissions and lost productivity of longer trips.[58] Select transit-oriented densification of certain districts of these cities can also start to shift mobility preferences by constructing residential buildings in close proximity to mass transit and walking and cycling options.

58 *An integrated perspective on the future of mobility*, a joint report from McKinsey & Company and Bloomberg New Energy Finance, 2016, Mckinsey.com.

Illustrative 2030 road maps by city context

The following examples illustrate two ends of the spectrum based on a city's specific context.

A Low-Income Mega City is semi-dense and has some transit-oriented infrastructure and mass transit ridership, but also suffers from crippling congestion and air pollution from high-emissions vehicles. These challenges encourage higher adoption of electrification and sharing. In the run-up to 2030, it focuses on a significant expansion of its public transit system and improved connectivity across existing transport options, particularly walking, cycling, and shared trips across a variety of electrified vehicles. Most of these vehicles are still human-operated, given the state of existing infrastructure and the complexity of traffic, but with fewer private internal combustion vehicles on the road, congestion and local air quality still improve significantly. These improvements contribute about 45 percent of the emissions reductions needed by 2030.

A Small, High-Income, Innovator City starts with high rates of walking, cycling, and mass transit ridership but faces increased congestion from greater use of package deliveries due to growing e-commerce and e-hailed vehicles. Its density and infrastructure enable accelerated uptake of autonomy, electrification, and shared mobility in moving both goods and people. In addition, this city continues to expand its seamless multimodal mobility services to encourage even greater use of walking and cycling infrastructure, mass transit and shared last-mile solutions. These measures blend private, shared, and public transport in the city and together achieve about 20 percent of the city's emissions target.

CHAPTER 2.4

Improving waste management

Improved waste and materials management is an important area of intervention for cities, since many cities have a significant amount of power over their waste systems. Tackling emissions from waste disposal can play an important role in ensuring cities achieve the emissions reductions needed for a 1.5°C trajectory, while having direct local impact and more broadly reducing the consumption of resources by cities. Our analysis shows that, while waste generally accounts for 10 percent or less of most cities' direct emissions, concerted efforts can reduce these emissions by half or more by 2030, contributing as much as 10 percent of the total emissions reductions needed.

However, these numbers only begin to paint the picture of the importance of addressing waste. Ninety-seven percent of global direct emissions from waste is methane, a greenhouse gas with 86 times the near-term global warming potential of carbon dioxide, making it an urgent priority for preventing the worst effects of climate change.[59] Reducing waste also has an outsize impact from a full life cycle perspective (which was out of scope for our modeling effort): for every kilogram of end-consumer waste, multiple kilograms of waste are generated upstream, such as in mining of raw materials or agricultural production, manufacturing and processing, and spoilage or damage during shipping, with fossil fuel energy consumed at each step. Overall, the United Nations Environment Programme estimates that improvements in waste management can achieve a 10 to 15 percent reduction in total global emissions, or up to 20 percent if waste reduction measures are included.[60]

The resilience benefits of improved waste management are also significant. By turning waste into inputs for local industries and avoiding bottlenecks for virgin materials, cities can become less vulnerable to shortages and fluctuations in commodity prices. Reducing food waste protects against food scarcity, especially in developing countries. And products of diverted waste such as compost and biogas can improve soil quality and provide low-carbon fuel for heating and transportation.

The opportunities

Cities can tackle waste emissions in a resource-effective way by adopting a "highest and best use" approach and preventing as much waste as possible from reaching each subsequent stage of processing. Conceptually, the waste management hierarchy has four broad levels: reducing waste upstream, repurposing as much useful finished product as possible, recycling and composting, and otherwise recovering materials for use, and managing disposal to minimize emissions of any remaining waste. At each step, biodegradable materials such as food waste, yard trimmings, and paper products are especially important to manage, since they account for all methane emissions from landfills and unmanaged disposal.[61]

59 *Global waste management outlook*, United Nations Environment Programme, 2015, unep.org.

60 *Global waste management outlook*, United Nations Environment Programme, 2015, unep.org.

61 "Technological and economic potential of greenhouse gas emissions reduction," *Climate change 2001: Mitigation*, Intergovernmental Panel on Climate Change, 2001, ipcc.ch.

Reducing the amount of waste generated is a major opportunity to decrease the full life cycle emissions of goods and services consumed within cities by requiring fewer total resources and less energy to deliver the same benefits to consumers. For example, cities can work with food businesses on better cold-storage systems and fresh produce handling to cut down on food spoilage before purchase. Through building codes and voluntary programs, city leaders can encourage more resource-efficient construction and demolition practices to cut the volume of building material waste sent to landfills. Repurposing items before they become waste, such as channeling excess food to nutritional assistance services or processing it for animal feed, makes productive use of finished goods rather than expending additional energy and resources to reprocess them.

While reducing, reusing, and repurposing waste tends to require deeper collaboration with the private sector, opportunities further downstream tend to be more within municipal control. Segregating waste and diverting it to recycling, composting, anaerobic digestion, mechanical biological treatment, and similar approaches can generate useful products such as raw materials, fertilizer, and biogas—which also reduce life cycle emissions by displacing the use of virgin materials. Recycling and organic-waste processing systems are often well suited to district-scale implementation, with the potential to create local jobs and improve neighborhood resilience. For the remaining waste that still goes to disposal, landfill gas capture systems can minimize methane emissions, and the captured gas can then be used as a lower-carbon energy source for electricity generation and heating.

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Breaking down barriers: How acceleration is possible

Innovative models for waste management can help cities rethink their need for traditional collection and disposal infrastructure and provide immediate benefits to the community as well as reducing greenhouse gas emissions. For example, community-based composting plants in Dhaka employ citizens to collect waste door-to-door by rickshaw bicycle systems and to separate organic waste from other items, providing income to poor residents, especially women. The compost product is sold to fertilizer companies and supports soil health for regional agriculture.[62] In Kolkata, a waste segregation project similarly employs local citizens and improves local air and water quality by reducing unmanaged burning and dumping. Since the program's launch, the city has reported a decrease in diseases attributable to air and water pollution, such as liver ailments and malaria.[63]

Forward-looking cities are already going further and planning the transition to a fully "circular economy," which shifts resource consumption from linear flows (raw materials to consumption to disposal) to continuous reuse. A circular economy integrates waste management with manufacturing processes and consumer life, ensuring that products and services are designed for reuse from the beginning and providing seamless connections to collect and redistribute materials. Cities across the world such as Amsterdam, London, and Phoenix have published road maps for circular economies and begun to put the necessary policies, partnerships, and infrastructure in place.[64] For all cities, this approach will become critical in the coming decades. Without progressive reductions in waste through the creation of alternative paths for material streams, cities' efforts to reduce direct emissions could be dwarfed by indirect emissions from increased consumption.

How cities differ

The starting point for waste management efforts varies widely across cities and largely shapes the approach they can take to achieve the greatest emissions reductions. For cities with high rates of unmanaged dumping and open burning, the most urgent priority is getting that waste into managed systems: establishing universal waste collection, ensuring sanitary processing, and capturing methane. For cities that already have full conventional waste collection in place, the main opportunities are in shifting from landfilling or incinerating to recycling and composting, as well as engaging the private sector to prevent waste upstream.

For example, for food waste in developing countries, the vast majority of the losses occur on the farm or in transportation and processes, while in developed countries, up to a third occurs at the consumer level.[65] Each of these scenarios requires engagement with different stakeholders and thus different engagement tactics to execute waste reduction actions.

62 "Organic waste is composted and sold as bio-rich fertilizer—reducing emissions, generating jobs and cleaning up the city," *C40 Cities*, November 3, 2011, c40.org.

63 "Cities100: Kolkata—Segregating waste leads to a better quality of life," *Cities100*, November 15, 2016, c40.org.

64 *London's circular economy route map*, London Waste and Recycling Board, June 2017, lwarb.gov.uk.

65 Ross Chainey, "Which countries waste the most food?" The World Economic Forum, August 13, 2015, weforum.org.

Developing countries also tend to produce higher proportions of organic waste relative to nonbiodegradable items, making programs such as waste segregation and composting particularly important.[66] Cities with waste that is predominantly organic can focus on treatment alternatives, while cities with enough disposal capacity can use full life cycle emissions to make the case for increased waste reduction and diversion.

66 "Waste composition," Chapter 5 in *What a waste*, World Bank, 2012, worldbank.org.

Illustrative 2030 road maps by city context

The following examples illustrate two ends of the spectrum based on a city's specific context.

A Large, Low-Income, Leapfrog City starts out plagued by air pollution from open burning of waste, as well as public health problems from unsanitary conditions in city streets and homes. Working with organizations that have proven business models in other similar cities, it launches programs to establish community-scale waste collection and segregation services as well as to build the market for recycled materials, compost, and biogas. In addition to creating jobs and improving health outcomes, this city brings previously unmanaged waste into formal collection and processing and diverts 20 percent of this waste to recycling and composting, contributing around 3 percent toward its total emissions target for 2030.

A Large, High-Income, Dense City builds existing collaborative relationships with local industries, retail businesses, and communities to establish the foundations of a circular economy. It partners with new mobility companies to create a reverse logistics network, which collects everything from uneaten food to old electronics to last season's fashions, and delivers them to new businesses that repurpose, repair, disassemble, and remanufacture to extend every material's useful life. Combined with consumer awareness programs to build demand for circular economy services, this city achieves near zero waste to landfills by 2030 and also contributes around 3 percent toward its total emissions target. ■

Chapter 3

ILLUSTRATIVE CITY ROAD MAPS

Illustration by Vic Kulihin

To show the scale of action that cities will need to undertake through focused acceleration to achieve their emissions reductions by 2030, we created sample road maps for six illustrative city types, which cover the majority of C40 city types.

As an example, a Large, Middle-Income, Semi-Dense City may have a carbon-intensive grid with only moderate decarbonization currently planned by its utility. However, its national regulations are favorable for renewables, and a combination of sunny climate and windy terrain means it has high potential for renewable electricity generation per unit installed. As its per capita income increases and summer temperatures rise due to climate change, cooling demand in its buildings is expected to grow, mostly in existing building stock, as the city's population is increasing only modestly. While few people currently have private cars, rising incomes mean that the city anticipates rapid growth in car ownership and congestion over the coming decades unless it can provide attractive alternatives for mobility, especially in the urban core.

Working within these parameters, the city focuses on accelerating a few highly visible initiatives to help educate and excite residents and create a feeling of a cleaner, more modern, resilient city. With moderate building density and good availability of rooftops and land, the city works with the utility and national regulators to rapidly build out a combination of utility-scale wind and solar farms as well as on-site and community-scale solar PV installations, with the goal of shifting grid mix from 20 to 80 percent zero-carbon by 2030. Rapid deployment of distributed renewables works in tandem with building upgrades, particularly as the city pushes for faster uptake of electric heat pumps and high-efficiency AC units that run off a higher mix of renewable energy. By 2030, 70 percent of AC units have been upgraded, 20 percent of buildings use electric heat pumps (with another 70 percent upgraded to high-efficiency oil or gas models), and 40 percent of suitable buildings have solar water heating—comparable to installation rates seen in cities in China and Scandinavia, as discussed in Chapter 2.2.

To enable alternatives to private vehicle ownership, the city accelerates densification through redevelopment and land use planning efforts in select districts. It also showcases the benefits of transit-oriented development in these districts, including new BRT routes, cycling-friendly streets, and wider, well-maintained sidewalks, resulting in a 6 percent increase in average density in the city and about 70 percent of trip distance covered by mass transit, walking, and cycling. Since local air pollution is a growing concern for citizens, A city's climate, history of climate action, and regulatory environment will influence the decisions about targets for efforts such as renewables deployment and transport initiatives.

vehicle electrification is another top priority, with the city committing to 100 percent of buses running on electricity by 2030, alongside EV-friendly measures (such as low-emissions zones, free parking, and charging) to electrify passenger vehicles.

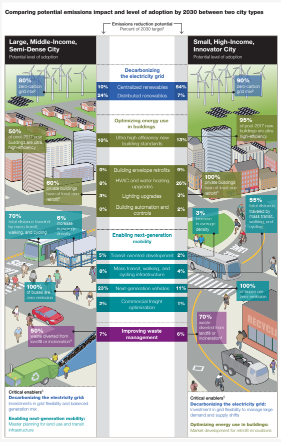
This Large, Middle-Income, Semi-Dense City, like many other urban centers, faces formidable challenges in accomplishing its emissions reduction goals by 2030 and charting a course to zero carbon by 2050. It must work closely with its utility to ensure investments in the grid are adequate to support the new abundance of electric vehicles-distributed renewable generation. It will also have to secure financing, incentives, and resources to build out new renewable generation assets at approximately twice the market-driven rate. Likewise, financing and cultivation of the real estate development community are needed at a large scale to enable multiple transit-oriented developments to open their doors by 2030. Partnerships with other governments and the private sector in the region can help phase out fossil fuel technologies in heating and cooking (such as oil and gas units) and fully replace them with attractive electric alternatives from 2030 to 2040. Some ideas on how the city might accomplish these tasks are laid out in Chapter 4.

By contrast, we can consider a very different city example: a Small, High-Income, Innovator City. With scant sunlight but abundant wind and hydro resources, it focuses its grid decarbonization efforts on centralized renewables. Residents are already well accustomed to multimodal transport and rarely use personal cars in the urban core. With this foundation, the city focuses on achieving full electrification of vehicles and promoting shared, connected mobility solutions. Since cold winters mean heating dominates building energy use, energy efficiency efforts focus on developing innovations in building envelope retrofits and low-carbon heating technologies.

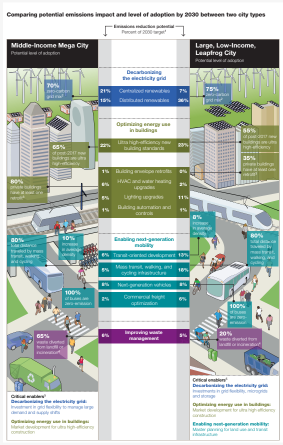
These two road maps illustrate how the decisions made by cities might differ. In each case, a city's climate, history of climate action, and regulatory environment will influence the decisions about targets for efforts such as renewables deployment and transport initiatives. However, despite disparate and unique paths, both cities achieve the emissions reductions needed for their respective 1.5°C trajectories for 2030.

An illustration of this comparison is shown in the executive summary (Exhibit A) along with two other comparisons of illustrative city road maps. Exhibit B shows a Middle-Income Mega City that faces similar growing pains but benefits from national alignment

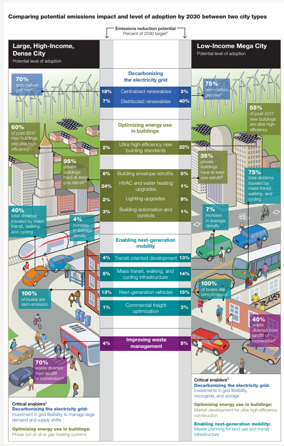
To compare the differences between a Large, Middle-Income, Semi-Dense City and a Small, High-Income, Innovator City, see **Exhibit A** on **page 11** in the Executive summary.



To compare the differences between a Middle-Income Mega City and a Large, Low-Income, Leapfrog City, see **Exhibit B** on **page 12** in the Executive summary.



To compare the differences between a Large, High-Income, Dense City and a Low-Income Mega City, see **Exhibit C** on **page 13** in the Executive summary.



with ambitious climate goals; it pursues the rapid build-out of large-scale, low-carbon infrastructure. In comparison, a Large, Low-Income, Leapfrog City is poised for transformative growth in both population and wealth through 2030; it seizes the opportunity to "leapfrog" to clean, integrated energy and mobility systems. Exhibit C shows a Large, High-Income, Dense City that has already addressed most of the "low-hanging fruit" areas and has limited direct control over its remaining emissions; it focuses on catalyzing change in privately owned assets. Illustrative actions by this city are compared with a Low-Income Mega City that is expanding rapidly and operates in a complex political and regulatory context; it focuses on making high-impact adjustments to shape how its built environment evolves. Together these illustrations show the paths that different cities might follow in pursing the 2030 emissions targets laid out in *Deadline 2020*. ■

Chapter 4

UNLOCKING CITIES' FULL POTENTIAL THROUGH CLIMATE ACTION

Pursuing a few large opportunities through a focused acceleration approach will allow cities to take bold action in the next decade to reach 2030 targets and build the capabilities they will need to hit 2050 targets. In addition, this approach generates immediate benefits for cities beyond future emissions reductions.

Benefits of climate action: New employment opportunities, greater productivity, and cleaner air

The New Climate Economy estimates that low-carbon urban actions present a global economic opportunity of $17 trillion by 2050.[67] The creation of new jobs will naturally be a part of this opportunity. The Environmental Defense Fund, for example, estimates that the United States alone will have more than four million sustainability jobs in areas such as energy efficiency, renewable energy, waste reduction, natural resources conservation, and environmental education.[68] In some cases, these positions will be new jobs, whereas in others they may represent a shifting of jobs from one sector to another. Infrastructure investment in new roads, for example, could be redirected to new mobility technology such as smart traffic lights in order to better use existing road infrastructure.

The large-scale deployment of climate solutions, especially when multiple cities in a region work together to invest in solutions such as electric vehicles and distributed solar, has the potential to boost labor demand from both manufacturers and installers. In general, the greater the proportion of investment that goes to installation, the larger the number of local jobs supported. For example, building efficiency upgrades will support local construction jobs as buildings are retrofitted. The 2012 retrofit of the iconic Empire State Building not only exceeded the projected energy costs savings of $4.4 million a year but also created 252 jobs.[69]

While economic output is crucial to a healthy urban ecosystem, the benefits of the four action areas extend beyond employment and productivity. Decarbonizing the grid, shifting buildings to cleaner technologies, and adopting next-generation mobility all dramatically improve air quality and local public health. In addition, many of the mobility solutions covered in this report can help relieve traffic congestion, which has multiple benefits for quality of life and productivity. In Buenos Aires, for example, its BRT system is estimated to have reduced commute travel time by as much as 50 percent, which is extremely important considering the greater productivity that can come from reduced traffic congestion and commute times.[70] Meanwhile, its Healthy Mobility project has reclaimed more than 7,000 square meters of street space for widened sidewalks and safer intersections, as well as creating a network of protected bike lanes and a bike-sharing

67 *Better cities, better growth, better climate*, a joint report from The New Climate Economy, C40 Cities, and World Resources Institute, June 2017, newclimateeconomy.report.

68 *Now hiring: The growth of America's clean energy and sustainability jobs*, a joint report from EDF Climate Corps and Meister, 2017, edfclimatecorps.org.

69 "Innovative Empire State Building program cuts $7.5M in energy costs over past three years," Empire State Building Sustainability, esbnyc.com.

70 "Buenos Aires expands BRT system with two new major corridors," a blog entry from C40 Cities, June 4, 2013, c40.org.

Decarbonizing the grid, shifting buildings to cleaner technologies, and adopting next-generation mobility all dramatically improve air quality and local public health.

system, increasing cycling trips sevenfold compared with previous levels, and improving safety for more than 400,000 vulnerable pedestrians in high-traffic areas, such as schoolchildren and hospital patients.[71]

New capabilities for cities

Building the capabilities to accomplish ambitious near-term goals in the four action areas will be critical to enabling cities to tackle the deeper transformations needed by 2050. These efforts will also unlock new opportunities to make cities more vital, responsive, and influential in areas outside of climate action. Several capabilities can support cities as they pursue their objectives.

Procurement strategies. Cities and networks of cities can influence the supply of sustainable products and services by communicating a near-term increase in demand to manufacturers and providers. For example, the California state government's green-building procurement rules helped stimulate both private sector adoption of the Leadership in Energy and Environmental Design (LEED) standard and investments in green-building expertise by local suppliers.[72] Similarly, an effort by 30 US cities led by Los Angeles aggregates the purchase of 114,000 electric cars and light trucks. The deal would be the equivalent to 72 percent of US plug-in electric-car sales in 2016 and is aimed at signaling to manufacturers that demand over the coming years will be robust.[73]

Innovative financing approaches. Cities represent about $700 billion in annual demand for urban infrastructure projects in sectors such as transportation and energy.[74] Yet city governments are often constrained by limited access to funding. Indeed, the World Bank estimates that just 4 percent of the developing world's 500 largest cities, and only 20 percent of cities in OECD markets, are deemed creditworthy in international markets, severely limiting their access to private finance.

71 "Cities100: Buenos Aires—Improving safety for cyclists and pedestrians," *Cities100*, October 30, 2015, c40.org.

72 Timothy Simcoe and Michael W. Toffel, *Government green procurement spillovers: Evidence from municipal building policies in California*," Harvard Business School working paper, number 13-030, May 2014, hbs.edu.

73 Stephen Edelstein, "30 cities join to explore $10 billion electric-car purchase," *Green Car Reports*, March 17, 2017, greencarreports.com.

74 John Hogg, "Financing sustainable cities: How we're helping Africa's cities raise their credit ratings," *The World Bank*, October 24, 2013, worldbank.org.

In the face of this challenge, some cities have developed creative ways to finance infrastructure investments including debt financing, public–private partnerships, and land value capture.[75] One of the most noteworthy of the latter is Hong Kong's "Rail plus Property" (R+P) business model. This program allows MTR Corporation, Hong Kong's railway operator, to make money from the increase in property value that typically follows the construction of rail lines.[76]

Other cities are increasingly exploring green bonds. These financial instruments are similar in structure to other municipal bonds, but funds are earmarked for projects that have a

75 Juergen Braunstein, Dan Dowling, Graham Floater, et al., *Financing the urban transition: A policymakers' summary*, Coalition for Urban Transitions, working paper, October 2017, newclimateeconomy.report.

76 Lincoln Leong, "The 'rail plus property' model: Hong Kong's successful self-financing formula," June 2016, McKinsey.com.

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positive environmental impact, a definition that is increasingly standardized.[77] In 2014, the City of Johannesburg used a green bond issuance to raise more than $140 million for a variety of projects including dual-fuel and biogas buses.[78] Gothenburg used its green bonds to finance projects from tree planting to district heating and sustainable housing initiatives.[79]

Further, civic models for sustainability projects should combine financing with the skills and technical assistance that increase the likelihood of success. A number of labs, such as C40 Cities Finance Facility, and the Inter-American Development Bank's Financial Innovation LAB, help cities develop the skills, technical expertise, and access to funding needed to unlock private sustainable infrastructure investment dollars. The Financial Innovation LAB, for example, has helped finance projects across South America, from LED street lighting to the construction of sustainable, efficient homes.[80]

Community engagement. Strategies that consider local cultural and political sensitivities alongside discussions of large-scale urban transformation can be more successful in the long run—especially when data alone are not sufficient to get approval for action from community audiences. Actions that are meaningful for communities in terms of increased equity, access, and quality of life are more likely to win the hearts and minds of communities.

For example, the City of Houston wanted to improve its public transit by developing a BRT system but received strong pushback from political stakeholders as well as concerned citizens. In response, project leaders shifted their communications and branding strategy to highlight the project's benefits.[81] The City of London has leveraged the support of local bloggers active in social media discussions to educate the public about the dangers of local air pollution and win public support for programs, such as bike-sharing, and investment in electric buses. And in Barcelona, the city created an entire citizen-led initiative on climate action, with more than 800 organizations participating; projects include training residents to renovate housing and a mobile application to exchange goods and services to reduce waste.[82]

Networks for information sharing. As cities delve into the details of implementing specific programs, they can take advantage of climate action networks to learn from other cities' successes and setbacks. Effective open dialogue can make a quantifiable difference: in 2015, C40 reported that 30 percent of climate actions completed by member cities were the direct result of collaboration with other cities. Bogotá and London, for example,

77 *The state of climate finance 2015*, Cities Climate Finance Leadership Alliance (CCFLA), December 2015, citiesclimatefinance.org.

78 *City of Johannesburg—Green bond*, SA Building Review, Volume 3, March 2015, sabuildingreview.co.za/viewonline; C40 News team, City Solutions, "Johannesburg the first C40 city to issue green city bond," C40, June 24, 2014, c40.org.

79 Projects funded by the Green Bond Program, City of Gothenburg, updated March 18, 2015, finans.goteborg.se.

80 "Promoting private investments in street lighting," Inter-American Development Bank, accessed October 30, 2017, iadb.org; "Ecocasa," Inter-American Development Bank, accessed November 7, 2017, iadb.org.

81 *Unlocking climate action in megacities*, C40 Cities, May 5, 2016, c40.org.

82 "Cities100: Barcelona—Citizen initiatives drive climate action," *Cities100*, November 15, 2016, c40.org.

Cities represent about $700 billion in annual demand for urban infrastructure projects in sectors such as transportation and energy.

have joined forces to lead the Clean Bus Declaration, which includes 22 other cities, to demonstrate the scale of demand to manufacturers. London has committed $510 million to upgrade 3,000 buses, and Bogotá aims to replace its fleet of 1,200 buses by 2020. Since the program's launch in 2015, the average price for a hybrid electric bus has already declined by 10 percent.[83]

Even advanced climate action cities can benefit from working with their counterparts. For example, New York's joint effort with Copenhagen brought Danish expertise in clean technologies to the United States to help address climate challenges.[84]

Once cities develop this broad tool kit of skills in support of climate action, they can apply these capabilities toward other priorities such as economic growth, socioeconomic mobility, regional connectivity, improved public safety, resilience, and disaster response. All these areas work to achieve the deeper emissions reductions cuts needed by 2050.

Convening and mobilizing other stakeholders to accelerate climate action in cities

Cities will need to take a leadership role in reducing emissions, but they will not be able to achieve the full 2030 targets on their own. To do so, they will need to proactively use their considerable convening power to mobilize the support of outside stakeholders. City governments that develop close relationships with and enlist the support of private sector companies, manufacturers, utilities, state and national governments, and other entities can also use their networks to make progress on initiatives beyond climate action.

Utilities can collaborate with cities to make the process of decarbonizing the grid faster, cheaper, and easier. Investments in smart grid technology that allow cities, companies, and individuals to monitor electricity usage, in combination with time-based rate structures, can help manage peak demand and reduce overall consumption. These investments can be lucrative for utilities as well, with the potential value of a fully deployed smart grid estimated to be as high as $130 billion annually in the United States alone,[85] and digital

83 "Cities100: London and Bogotá—Global procurement alliance boosts green transit," *Cities100*, October 30, 2015, c40.org.

84 *Connecting cities to deliver climate action*, C40 Initiatives & Networks, 2016, c40-production-images.s3.amazonaws.com.

85 Adrian Booth, Mike Greene, and Humayun Tai, *US smart grid value at stake: The $130 billion question*, June 2010, McKinsey.com.

optimization of the grid shown to boost utility profitability by 20 to 30 percent.[86] As discussed in chapter 2.1, utilities can also take the lead in building renewable generation assets and streamlining their integration into the grid. In some regions where conditions are right, utilities are already moving forward based on cost alone. Xcel Energy, for example, recently announced that it will build a major new windfarm in the US Midwest without full federal wind production tax credits because wind is now among the lowest-cost energy sources.[87]

Over the past decade, utilities have struggled with deploying more expensive renewable energy technologies in the face of declining demand due to energy efficiency initiatives. Electrification of the transport system now offers utilities a historic opportunity for growth. Utilities can play a role in enabling electrification through programs that range from providing rapid-charging infrastructure at residences to helping cities devise and install charging infrastructure throughout the city. One innovative idea would allow utilities to finance the approximately 50 percent higher up-front cost of purchasing electric versus diesel buses with a tariff paid back through a monthly charge on the transit agency's utility bill.[88] While this model has not yet been executed in the transport sector, it has a long history of success in the building energy efficiency retrofit market.

The urban private sector will play a critical role in cities' ability to achieve emission reductions in buildings, industrial processes, and waste, but they also stand to benefit. As described in chapter 2.2, many of the actions building owners can take will pay back quickly in lower utility bills, but barriers include cash constraints for the up-front investments and split incentive problems where building owners invest but their tenants benefit. Financing solutions (both from private as well as public providers) can help overcome the initial investment hurdle. For example, many cities offer incentive programs that lower the cost of energy efficiency retrofits. In addition, building owners are increasingly finding that green buildings can command higher rental or lease rates due to lower utility bills while increasing higher worker productivity and satisfaction. These buildings also tend to be in higher demand leading to lower tenant turnover and time spent vacant.

Much of the responsibility of accelerating industrial efficiency resides with manufacturers, which can help cities by making operational improvements to plants to reduce energy use and influencing suppliers to do the same. However, cities can encourage these changes by creating reliable demand for the low-carbon products produced after these improvements. On the other hand, as sustainability becomes an increasingly visible issue, the demand for green products and services has grown in some places and at times outstripped supply.[89] If cities can help drive a consistent signal, manufacturers and vendors can

86 Adria Booth, Niko Mohr, and Peter Peters, *The digital utility: New opportunities and challenges*, May 2016, McKinsey.com.

87 Chris Clark, "Wind and solar energy: Clean affordable, reliable and secure," *MinnPost*, October 6, 2017, minnpost.com.

88 "Tariffed on-bill finance to accelerate clean transit," Clean Energy WORKS, accessed October 30, 2017, cleanenergyworks.org/clean-transit.

89 *GreenBiz*, "Businesses scramble to keep up with green product demand," blog entry by BusinessGreen Staff, May 24, 2012, greenbiz.com.

help accelerate change by increasing production, which also helps them achieve economies of scale to bolster the cost-competitiveness of low-carbon products and services.

Regional and national governments control a range of incentives and financing that both directly and indirectly affect cities. For example, energy efficiency standards for buildings and vehicles are often defined at the national level. Similarly, financing of major municipal infrastructure investments such as mass transit projects is also often controlled by regional or national governments. These types of large infrastructure investments lay the foundation for more efficient, productive, and accessible cities.[90] An example is China's proposed deadline to phase out sales of fossil fuel-powered vehicles.[91] This move combined with economic incentives has already resulted in fully electric buses accounting for 20 percent of new buses sold in China in 2016.[92]

■ ■ ■

Cities are increasingly finding that incentives to support ambitious climate action are aligning for the private sector, utilities, and state and national governments. Where they do not, many cities are taking decisive action to mobilize stakeholders through policies and incentives for private investments. Taking advantage of other stakeholders' willingness to support city climate action will require strong city leaders to fully harness their convening power and demand change even beyond their jurisdictional boundaries. ■

90 *Better cities, better growth, better climate*, a joint report from The New Climate Economy, C40 Cities, and World Resources Institute, June 2017, newclimateeconomy.report.

91 Bloomberg News, "China fossil fuel deadline shifts focus to electric car race," *Bloomberg Technology*, September 10, 2017, bloomberg.com.

92 James Ayre, "China 100% electric bus sales grew to ~115, 700 in 2016," *Clean Technica*, February 3, 2017, cleantechnica.com.

CONCLUSION

Cities present a major opportunity in the commitment to bring the world in line with a 1.5°C climate change pathway. They represent more than half the world's population, are engines of economic growth, and are responsible for more than 70 percent of global greenhouse gas emissions. As such, they have a tremendous responsibility, which many city leaders and citizens are taking seriously. Already cities around the world are innovating and piloting new ideas, passing regulation, creating incentives, and educating stakeholders about the challenge. But more needs to be done. If cities are to achieve their emissions reduction targets, they must rapidly deploy new cleaner technologies and infrastructure at an unprecedented scale and speed.

The complexity of an urban social and political ecosystem can make the design and implementation of climate action seem overwhelming. And the myriad options for reducing greenhouse gases can leave cities paralyzed. This report offers a set of 12 opportunities grouped across four action areas that are no-regrets actions for cities. To achieve the full potential of these opportunities, there are three priorities.

Cities must move beyond quick wins. Focused acceleration by cities moving decisively and at scale in this report's four action areas has the potential to help cities achieve 90 to 100 percent of the emissions reductions needed by 2030 and position them for even deeper cuts by 2050. Focused acceleration is a strategy that has helped private sector organizations achieve ambitious goals in equally complex situations. Cities that use the next 12 years to build a world-class tool kit that includes streamlined procurement, access to capital, relationships with other cities for best-practice exchange, community engagement, and partnerships with the private sector and government will be prepared to tackle the next set of emissions reduction opportunities. Achieving 2030 target reductions will also lay the foundation for capturing opportunities that take longer to play out—such as densification and land use planning—but will be critical in achieving the deeper decarbonization required to meet 2050 targets.

Cross-sector collaboration will be essential. Achieving a 1.5°C pathway through climate action will require significant collaboration across all sectors and levels of government. In our work across different sectors, we have already seen an acceptance that all parties have a role to play in reducing carbon emissions. An increasing number of companies are already working toward goals of 100 percent renewable energy and can use what they have learned to partner with cities and utilities to make this goal a reality across the global urban landscape. Similarly, collaboration among automotive and technology companies, utilities, and cities can accelerate trends in mobility that have the potential to move cities toward lower-carbon, more efficient, and accessible mobility for all. Infrastructure also offers an opportunity for cities to collaborate with real estate developers and building owners that recognize building and maintaining efficient buildings can reduce utility bills for occupants, lower tenant turnover, and boost worker productivity.

Mayors and other city leaders will need to win support for change. Building consensus for climate action among stakeholders within local populations and business communities requires highlighting the benefits beyond the reduction of greenhouse gas emissions. Benefits are both economic, social, and environmental, including reduced road congestion and air pollution, greater productivity among workers, improved quality of life, increased resilience, road safety, and shorter commute times. Engaging community groups and designing climate action plans with their input can also help ensure that the transition to a low-carbon city is an equitable one for all residents. Mayors can highlight these benefits in making the case for today's investments in our long-term collective future. ■

ACKNOWLEDGMENTS

C40 team
Mark Watts
Kevin Austin
Malcolm Shield
Michael Doust
Simon Hansen
Shannon Lawrence
Joshua Gardner

McKinsey team
Stefan Knupfer
Shannon Bouton
Cynthia Shih
Devansh Gupta
Shelby Lin
Shannon Gombos
Stephen Jacobson
Andreas Venus
Brodie Boland
Peter Hill

This report involved collaboration across many people. We would not have the space to thank each of them by name, but we would like to recognize the individuals below for their expertise and generosity with their time. The impact of this report will be the product of their collective contributions:

Desiree Bernhard, Michele Bertoncello, Alex Brotschi, Lia Cairone, Ricardo Cepeda-Márquez, Robert Cervero, Flavio Coppola, David Craven, Andrea Fernandez, David Frankel, Bhavin Gandhi, Anna Gressel-Bacharan, Clare Healy, Max Jamieson, Laura Jay, Sean Kane, Kate Laing, Nicholas Laverty, Julia Lipton, Timo Möller, Eric Morden, Jesse Noffsinger, Dickon Pinner, Angelos Platanias, Matt Rogers, Josh Rosenfield, Caterina Sarfatti, Lucila Spotorno, Zachary Tofias, Andreas Tschiesner, Helga Vanthournout, Amy Wagner, Caroline Watson, Jonathan Woetzel, Katherine Wolosz, and Hong Xia

Contacts for this report

Kevin Austin
kaustin@c40.org

Malcolm Shield
mshield@c40.org

Simon Hansen
shansen@c40.org

Stefan Knupfer
stefan_knupfer@mckinsey.com

Shannon Bouton
shannon_bouton@mckinsey.com

Cynthia Shih
cynthia_shih@mckinsey.com

November 2017