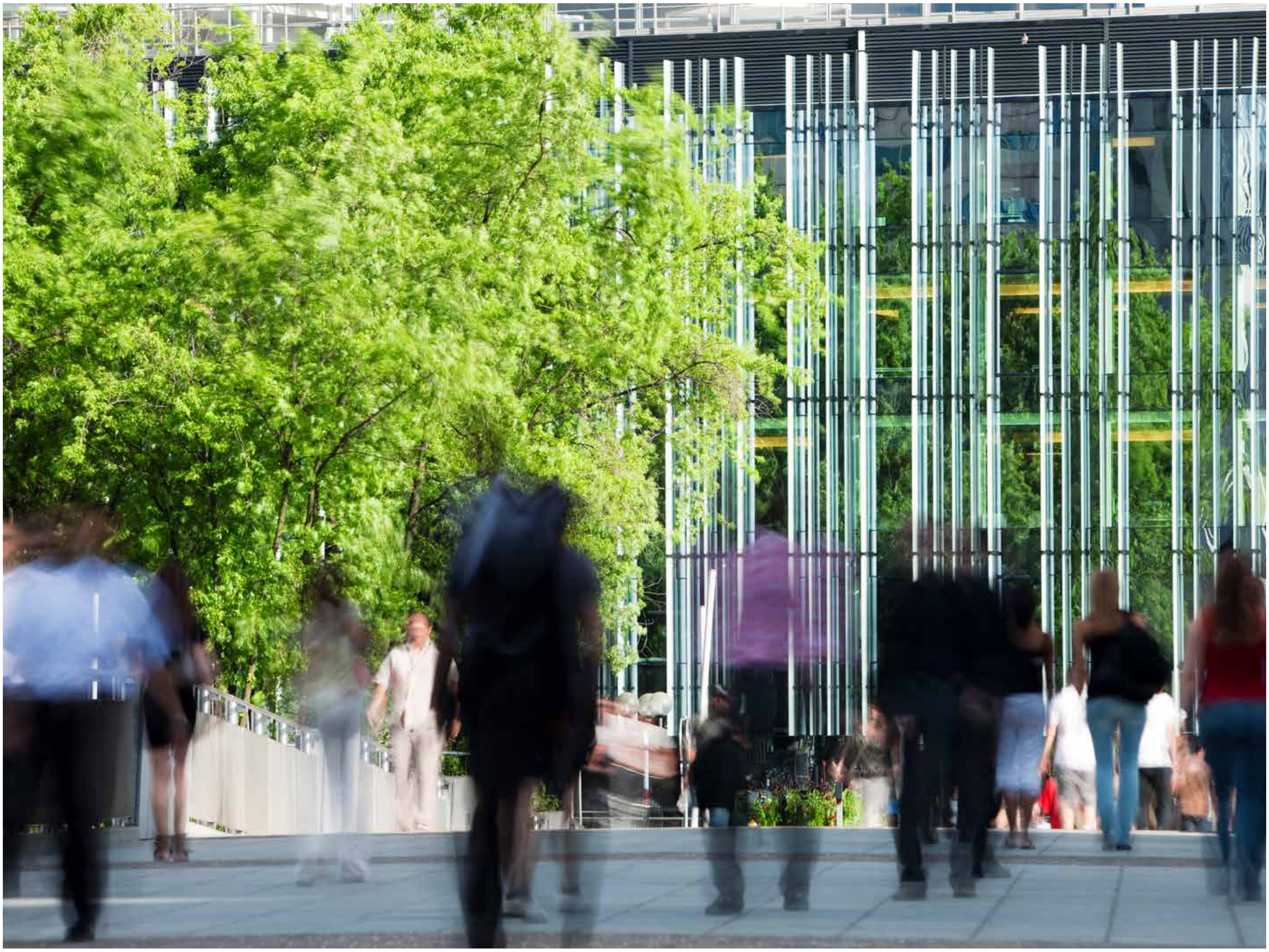

Building Urban Futures

City Carbon Actions Anchored in Building Codes and Standards

SEPTEMBER 2018

By Karen Weigert,
with Samuel Tabory and
Maddie Koolbeck

THE CHICAGO COUNCIL ON GLOBAL AFFAIRS

Report support

For further information about this study, please write to the Chicago Council on Global Affairs, Two Prudential Plaza, 180 N. Stetson Avenue, Suite 1400, Chicago, IL 60601, or visit the Council's website at thechicagocouncil.org.

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EXECUTIVE SUMMARY

A century ago, the world was largely rural. Today, construction of tall skyscrapers and low-slung buildings is expanding cities from Accra to Zurich. Buildings anchor two systems—energy and urban mobility—and drive economic growth. At the same time, carbon dioxide (CO_2) emissions from buildings are directly responsible for 50 percent or more of an urban area's total carbon footprint. Within this widespread and extraordinary impact lies tremendous potential for cities to shape the future.

In some parts of the world, the buildings of the future are already largely built but in need of renovation.* In other markets, new construction will be transformative. Global building square footage is projected to double between now and 2050. In many of the places likely to see huge increases in construction, building energy codes, which guide the long-term energy and carbon impact of buildings, are not in place.

* The markets defined in the report follow the World Bank income classifications. "Established market" corresponds to high-income countries, "middle-income market" corresponds to the high-middle-income countries, and "developing market" corresponds to lower-middle-income countries.

The global building boom will shape the economic prospects as well as the health and well-being of current and future urban residents. Low-carbon buildings—those that pair high energy efficiency with renewables and emit little or no net carbon—have the potential to reduce global building energy use by 50 percent and CO_2 emissions by 84 gigatonnes by 2050. Global energy-efficiency improvements alone could lead to monetary savings of between $360 billion and $530 billion. Across all economies, low-carbon buildings are linked to health by reducing outdoor and indoor air pollution, improving comfort and well-being, and reducing risks from climate change.

Building codes and standards are a foundation of this transformation. From mandatory base codes to pioneering innovation standards, requirements and incentives define new building construction and existing building renovation. These guidelines can influence many of the critical decisions made in early design phases that determine building energy use and carbon impact, directly shaping the energy needed to heat, cool, and operate a building as well as the energy used in transportation. Codes and standards also push for improvements to ongoing operational performance and can address embodied energy, or energy emitted during material production, on-site construction, and final demolition and disposal.

But while the potential of building energy codes to reduce emissions is clear, they are not as strong or widespread as buildings themselves. An estimated 100 billion square meters of new construction is expected in countries without mandatory building energy codes. A consistent set of principles, however, can frame the work needed by city governments and their public, private, and nonprofit partners to shape thriving, low-carbon cities. (See “Principles for thriving, low-carbon cities anchored in building codes and standards” on the following page.)

Across markets, building energy codes must be established, strengthened, and enforced. New and bolder codes must take root to foster deeper carbon reductions across all phases of a building’s life span. To make significant progress, cities must pair these efforts with policies that link buildings to sustainable mobility solutions and a decarbonized electricity supply—and they must look to collaborate with other levels of government and the private sector.

It is no easy task, and it is one that will require tailored actions and strength across cities and markets—but the benefits will reach every corner of society, from the economy to human health, today and for decades to come.

Principles for thriving, low-carbon cities anchored in building codes and standards

1. **Treat building energy codes as part of a larger transformation:** Building energy codes and low-carbon building practices are part of a larger plan for a thriving city.

2. **Develop ambitious and appropriate building energy codes in all markets:** Every jurisdiction in the world needs bold energy codes that are appropriately tailored to the local context and apply to new construction and renovations.

3. **Implement robust enforcement and tracking mechanisms:** The existence of codes does not guarantee building performance; achieving compliance requires implementation and enforcement.

4. **Ease compliance challenges through knowledge building and incentives:** Local knowledge and capacity must be strengthened and unleashed when new codes or requirements are introduced.

5. **Foster leadership buildings and platforms in every market:** Every market needs visible collaborations, commitments, and demonstration projects to deliver the potential of low-carbon buildings.

6. **Link codes to larger decarbonization efforts in energy supply, compact city development, and transportation:** Building codes are crucial, but a building's ongoing energy supply, location, site orientation, and ties to mobility contribute to carbon outside of operations.

7. **Account for energy use throughout a building's life span:** The full carbon impact of a building includes embodied energy; materials, construction, and demolition need to be addressed.

8. **Drive energy impact outside of codes through incentives, appliances, and bulk procurement:** Not every energy use is covered by codes even when they exist; priority uses can be addressed directly.

9. **Support research and innovation:** The future must be shaped, from new technologies to stronger scaling and better understanding of policy and practice.

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INTRODUCTION

Looking at cities from afar, what is first visible is not the people or the food—it is the buildings. From all sectors and in various sizes and styles, buildings shape the city. The buildings defining skylines from New York City to Accra, Ghana, also anchor their cities' economic strength and determine their climate impact.

Building construction and the wealth represented in buildings are concentrated in cities. The building sector accounts for between 5 and 10 percent of the gross domestic product (GDP) of every country in the world[1] and represents 50 percent of global wealth.[2] Buildings also steer the energy and carbon profile of urban areas and their home countries.

Buildings are also responsible for approximately 36 percent of global energy use and 39 percent of energy-related CO_2 emissions.[3] In large cities globally, buildings are responsible for nearly 50 percent of urban greenhouse gas emissions.[4] This percentage exceeds 70 percent in many mature cities, including New York City and London.[5]

Lower CO_2 emissions can offer significant rewards. Both cities[6] and nations[7] have shown that emission reduction can align with economic growth, and the cost savings from energy-use reductions can be tremendous.[8] With global pressure to both meet the needs of rapidly growing urban populations and address the most dangerous effects of climate change, the need for immediate, comprehensive action is clear.

Urban population growth is spurring city and building development

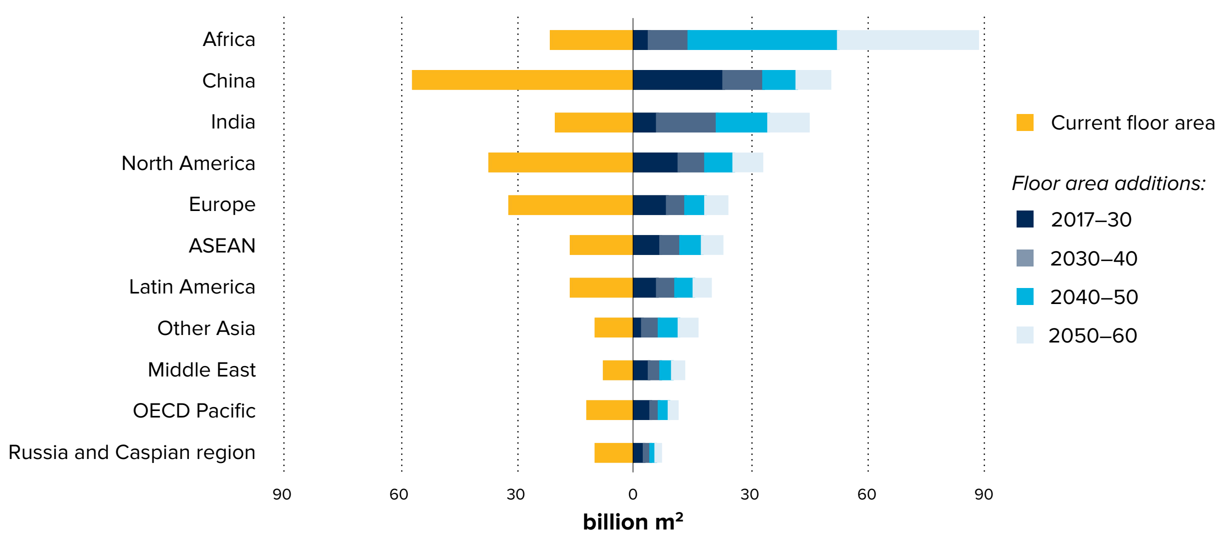
The scale of the building sector today is extraordinary. The existing global building floor area covers 240 billion square meters (Figure 1). Fifty-two percent of that floor area exists in three global regions—Western Europe (32.0 billion square meters) and the United States (37.3 billion square meters), both of which are largely urbanized, and China (56.7 billion square meters), where recent urbanization has transformed the country with more to come.[9]

In cities that have long been urban centers—places like London, Tokyo, and Toronto—the existing floor area will dominate the carbon profile in the decades ahead. In these cities and their nations overall, today's buildings will account for 65 percent of total building space in 2060.[10]

Globally, however, the story is radically different. With an anticipated urban population increase of 2.5 billion people by 2050,[11] a massive global building boom lies ahead. By 2050, building square footage is expected to grow by more than 230 billion square meters, essentially doubling the global building stock that exists today.[12]

The growth is expected to extend across the globe. In the first major wave, from 2017 to 2030, developing and middle-income countries will see the vast majority of total building construction. China alone will account for 22.9 billion square meters of growth. The profile is expected to shift in the second wave; from 2030 to 2050, developing economies will account for a majority of all

Figure 1: Global growth in building square footage will extend across the globe.



Note: "OECD Pacific" includes Australia, Japan, New Zealand, and South Korea; "ASEAN" is the Association of Southeast Asian Nations.
Source: International Energy Agency, *Energy Technology Perspectives 2017,* June 2017, www.iea.org/etp.

WITH AN ANTICIPATED URBAN POPULATION INCREASE OF 2.5 BILLION PEOPLE BY 2050, A MASSIVE GLOBAL BUILDING BOOM LIES AHEAD.

building growth. During this period, Africa and India will add 48.7 billion and 28.4 billion square meters of floor space, respectively. From 2050 to 2060, Africa will be the largest contributor to global floor space growth, with expected growth of at least 30 billion square meters in that decade alone.[13]

Tucked in this unprecedented transformation is the question of the building energy codes and standards that will guide buildings and the cities they shape. Today, close to 70 percent of global building energy use is not covered by mandatory codes or standards, two-thirds of countries lack new construction building energy codes, and there are no large-scale mandated energy codes that require zero-carbon buildings.[14] Over the next 40 years, the current trajectory will see more than 100 billion square meters of floor space built in locations without mandatory codes.[15] The critical time to act is now.

There is global consensus on the need for low-carbon buildings

To date, the Paris Agreement is the most comprehensive attempt to address CO_2 emissions globally, reflecting the position and possibilities of each nation through unique nationally determined contributions (NDCs). Of the 193 NDCs submitted by countries around the world, almost 70 percent directly mention the building sector,[16] about one-quarter are explicit in the need for increased energy efficiency and/or renewables in buildings, and about 20 percent directly mention building energy codes.[17] In the best-case scenario, existing NDCs will increase the amount of global building emissions covered by such policies to 60 percent, from 47 percent.[18] The influence of the Paris Agreement has also reached local governments, with more than 9,000 mayors committing to the Global Covenant of Mayors, a pledge to meet the Paris Agreement objectives through action at the municipal government level.

The benefits of low-carbon buildings and cities stretch across the globe, and the global consensus supports focused action. From the core economics of construction and lower operating costs to local health and the global effort on climate change, action on buildings strengthens cities overall.

Globally, low-carbon buildings shaped by building energy codes have the potential to reduce energy use by 50 percent and carbon emissions by 84 gigatonnes of CO_2 by 2050 through energy-efficiency improvements and the use of renewable energy. These reductions would lead to estimated monetary savings of between $360 billion and $530 billion.[19]

Green construction can also serve as a major economic driver in cities. For example, low-carbon buildings in the United States accounted for 3.9 million jobs between 2015 and 2018.[20] And in 2014, the construction of green buildings in Canada contributed $23.5 billion to GDP and created jobs for 297,890 people, outpacing the combined employment of the forest, oil and gas, and mining industries.[21]

Looking ahead at the coming two decades, the International Energy Agency (IEA) estimates that "economically viable" energy-efficiency investments across the full spectrum of energy use have the potential to generate an additional $18 trillion in global economic output by 2035. Reduced public spending on energy in Europe alone could save an estimated $44 billion to $55 billion annually. That number grows substantially when taking into account the potential economic benefits of redeploying those saved funds for other public uses.[22]

The benefits of clean-energy efforts go beyond carbon

The benefits of low-carbon building efforts go well beyond direct carbon mitigation and direct economic benefits. The impact of additional direct and indirect health and local environmental benefits could be substantial.

The Intergovernmental Panel on Climate Change identified general clean-energy efforts as having a particularly significant impact on the health and well-being of individuals in developing economies. Reducing indoor air pollution from the use of dirty cooking fuels and supporting overall increased access to modern levels of energy service have implications for key human development measures.[23]

Across all economies, low-carbon buildings are linked to health both as a function of reducing outdoor air pollution emissions through avoided fossil fuel–powered electricity generation and by improving occupant comfort and well-being. Reductions in fossil fuel–powered electricity lead to health benefits assessed at $2, $7, and $46 per ton of CO_2 in the European Union, China, and India, respectively.[24]

Looking at individual buildings, researchers have estimated that low-carbon buildings can double employees' cognitive scores and greatly reduce respiratory issues.[25] Overall, several full assessments of energy-efficiency investments, measuring economic and health impact, have found that the cost-benefit ratios can be as high as four to one, with as much as three-fourths of that overall benefit coming from the health and well-being impact of such investments.[26]

The impact of low-carbon buildings also extends to avoiding climate-related health risks. For example, white roofs reflect heat, lowering extreme temperatures by 2 degrees Celsius or more[27] and helping address the heat island effect—that is, when urban areas are hotter than surrounding rural areas due to built structures (often with dark surfaces) and human activities. Features such as sun-reflective roofs ultimately reduce the electricity demand for air-conditioning (in buildings that have it) and protect human health from dangerously high temperatures.

Both the United Nations' 2030 Sustainable Development Goals (SDGs) and the related New Urban Agenda adopted at the Habitat III convening in October 2016 envision an explicit role for clean-energy and efficiency efforts in delivering broad-based sustainable development and resilience goals, in cities and elsewhere. SDG 7 calls for ensuring clean and affordable energy access for all, with target 7.3 specifically calling for doubling "the global rate of improvement in energy efficiency"[28] by 2030. SDG 11 broadly calls for making human settlements inclusive, safe, resilient, and sustainable, with target 11B calling for a substantial increase in the number of cities "adopting and implementing integrated policies and plans toward inclusion, resource efficiency, mitigation and adaptation to climate change, and resilience to disasters."[29]

Low-carbon building efforts, anchored in both code and noncode action alike, have a key role to play in delivering on both the sustainability and resilience targets embedded in these goals. The consistency with which resource efficiency is emphasized across multiple SDGs and their targets highlights the multiple benefits and the broader return on investment for low-carbon building sector efforts.

Despite all the data, research, and initiatives demonstrating the global consensus on the benefits of low-carbon buildings, there is much work to be done on implementation, specifically in low-carbon city actions anchored in building codes and standards.

To build on the ongoing work in this field, this report looks at markets around the world and at specific cities that are operating within them. It charts a course for improved adoption and implementation of building codes and related policies to work toward low-carbon buildings and thriving, low-carbon cities worldwide.

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LOW-CARBON CITIES ANCHORED IN LOW-CARBON BUILDINGS

1

Every day buildings consume energy to serve their basic functions, driving approximately one-third of global energy use.[30] For existing buildings, the energy used during operations and the expense and related CO_2 emissions are a critical focus. The impact of a building, however, begins before and extends after operational use. A building's carbon impact starts with its construction and the materials used and continues through the demolition process. During its life span, a building shapes urban CO_2 emissions from the energy sources it uses and the transportation systems that bring people to it. In the process, buildings define the broader landscape of a city—from its look and feel to the energy and transportation systems that make it run.

Buildings activate energy use in cities

UN Environment and the International Resource Panel identified energy-efficiency and conservation behaviors, many linked to green building upgrades, as key levers in driving overall resource efficiency in cities. When layered on top of compact urban form and then coupled with increased renewable-energy penetration and even cross-sector resource exchanges (e.g., using fly ash from power plants in construction materials or reusing industrial "waste" heat in district energy systems for heating and cooling buildings), larger resource-efficiency strategies in cities, of which building codes are a part, could help foster reductions in overall urban resource use by up to 90 percent.[31]

To think of it in basic terms, an efficient building needs to be designed and constructed well, using appropriate and efficient materials, and then operated well over time. That same building needs to be powered with low-carbon energy and located in the right place to link to larger transportation and sustainable mobility efforts. Performance needs to increase over time and scale to buildings worldwide. Nine distinct principles can guide work in cities around the world in delivering those aspects of buildings and cities (Diagram 1). These principles, which are described in detail in "Nine

Diagram 1: Nine principles can guide work in cities around the world

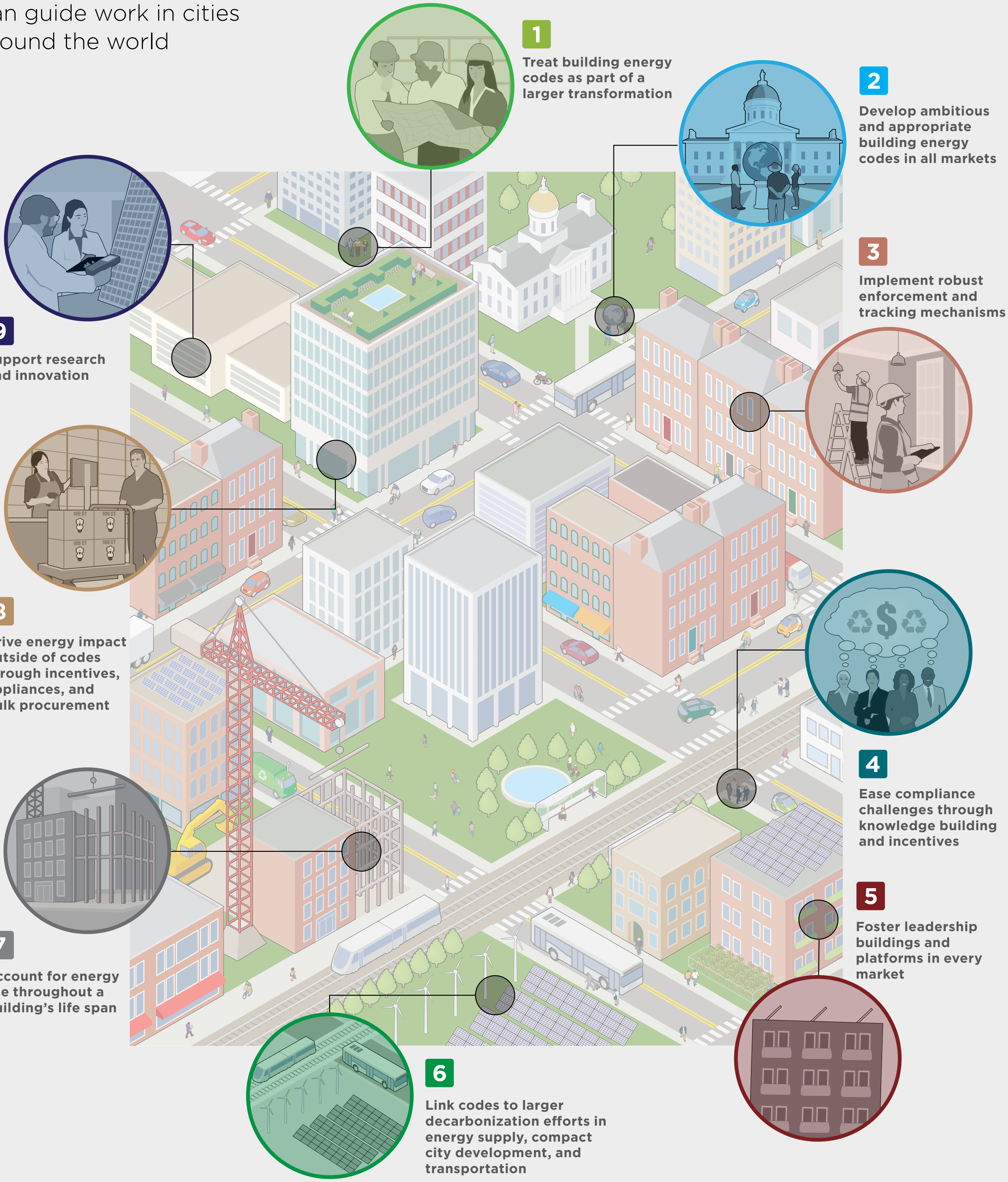

Illustration by Vic Kulihin

principles for low-carbon city actions anchored in the building sector" on pages 44–54, come to life in examining cites and buildings today (see "Matching strategies with markets and pathways" on pages 24–43).

Operations drive energy consumption in buildings

Operational energy use is estimated to account for the vast majority of lifetime building energy use.[32] The primary contributors to energy consumption within buildings differ by climate and building type, but they generally include space conditioning (heating or cooling), water heating, refrigeration use, lighting, and equipment and appliance use (often referred to as plug load).

Building energy use profiles look different across national or regional contexts but also across building types—residential and commercial—within the same market. For example, energy end use in US commercial buildings is dominated by heating (25 percent), while cooling (9 percent) and water heating (7 percent) are smaller shares of total end use.[33] The trends are different in US residential buildings, with cooling representing the single largest share of end use (17 percent), and space heating and water heating representing close second-order shares of overall end use (15 percent and 14 percent, respectively).[34]

A look at one building type across different markets—office buildings in Beijing, China, and Berkeley and Merced, California—demonstrates the variance in the major categories of energy use. In all buildings, three types of usage dominate the load: heating, ventilation, and air-conditioning (HVAC); lighting; and office equipment. HVAC contributed 25 to 50 percent of all energy use. Lighting accounted for 50 to 60 percent of energy consumption in the Beijing buildings while only accounting for 25 to 30 percent in the California buildings. And office equipment accounted for 30 to 60 percent of California buildings' energy use and only 10 to 12 percent in Beijing buildings.[35]

Many of the critical decisions that influence building operational energy use are made in early design phases. These decisions directly shape the amount of energy used to heat, cool, and operate a building over its lifetime—decisions such as building size, form, and orientation; window location; shading; the insulation of the exterior walls; and the type of equipment installed to condition the interior. For example, in cold-climate developed countries, a building with a high-performance envelope[**] uses only 20 to 30 percent of the energy currently required to heat a typical building.[36] Decisions about the layout of buildings have a direct impact by influencing daylighting, natural ventilation, passive solar heat gain, passive cooling, and the performance of on-site solar generation.

Operations are also shaped by multiple ongoing decisions. Occupants of a building have a large impact on building energy use through decisions on the type of appliances and equipment to use

**"Envelope" is a common term that refers to the exterior or shell of a building—the roof, subfloor, exterior doors, windows, and walls. A "high-performance envelope" is one designed to conserve energy within the building.

ELECTRICITY FROM APPLIANCES, HVAC EQUIPMENT, LIGHTING, AND OTHER USES WILL MAKE UP 40 PERCENT OF THE PROJECTED RISE IN FINAL ENERGY USE IN THE COMING DECADES.

and, subsequently, the amount of electricity to use. Electricity from appliances, HVAC equipment, lighting and other uses will make up 40 percent of the projected rise in final energy use in the coming decades.[37]

Appliance efficiency standards that have an impact on frequently used items in homes and businesses, such as air-conditioning units, can play a large role in reducing this operational energy use. Typically, appliance standards fall outside of building energy codes and are under national authority, but on a city level, incentives, efforts to lower costs for consumers through bulk procurement, and educational programs on energy use can foster a transition to more energy-efficient appliances and actions.

There are also critical ongoing decisions, made by owners or developers of buildings from both the public and private sectors, that have a substantial impact on lifetime energy use. Good maintenance can lower ongoing needs for energy, while retrofits can offer a chance to "reboot" the overall energy profile of a building. The retrofit and investment cycle is a critical element in shaping the future energy use of existing buildings.

Building support systems—including energy supply and mobility—help shape the carbon profile of a city

Two broad systems in cities—energy supply and mobility—are shaped by buildings, and cities have a range of tools to address them, including building energy codes. Buildings are key demand centers for energy, accounting for 55 percent of total electricity demand globally.[38] They also shape urban mobility, defining the transportation needs of people based on where they live, work, learn, and play. Buildings located near transportation infrastructure or near other places of interest can make transit or walking desirable options. Looking ahead, energy and transportation systems will be increasingly interconnected as transportation is electrified.

The locations of buildings throughout the city, influenced by urban planning, directly affect transportation emissions. Specifically, urban density and the jobs-housing balance in a city have key implications for sustainable mobility. Medium- to high-density urban areas, where buildings serve as central locations in an integrated transit and mobility system, can lay a foundation for reduced CO_2 emissions and pollution as a result of reduced travel demand and lower pollution (from shorter or fewer trips as well as a shift toward public transit or zero-carbon activities such as walking and biking).[39] Detailed analyses of emissions in advanced economies show that urban residents typically have lower per capita emissions compared with residents elsewhere in the same country.[40] In Chicago, for example, households within a half mile of a transit station have 43 percent lower auto emissions than the city average; for those close to downtown, emissions are 78 percent lower.[41] While other factors are at play in influencing daily travel behavior, dense and mixed-use environments represent a key building block for compact urban form and associated sustainable mobility impact.

On a closely related note, urban planning also directly affects CO_2 emissions by shaping the amount of green space in a city. Urban green space mitigates the urban heat island effect, generally decreasing temperature highs, reducing energy used to cool the city, and reducing the stress heat can cause for residents.

Growing capabilities in technology allow buildings to become energy producers as well as energy consumers. Starting with on-site renewables and extending into storage for renewable power and dynamic grid interactions where buildings can quickly reduce usage when the grid is under stress, buildings can help shape clean-energy transitions within cities. For example, the integration of solar panels onto suitable rooftops in Mumbai could satisfy between 19.7 and 31.1 percent of daily electricity demand.[42] Urban layout of buildings can also affect energy systems. District energy systems—shared heating and cooling of buildings in an entire city district—are credited with reducing CO_2 emissions in Copenhagen, Denmark, by nearly 70 percent.[43] Buildings can anchor clean-energy systems, particularly in densely populated areas.

Looking ahead, buildings can serve as infrastructure for electric-vehicle charging stations as well as for larger battery storage efforts, aiding in a transition away from internal combustion engines and toward electric vehicles (EVs) while also providing services to the electric grid. Car batteries can become external storage for the existing grid. The European Union recently passed a mandate for any large new nonresidential building to have at least one charging point. In addition, the US city of Atlanta, Georgia, requires 20 percent of the parking spaces in all new parking structures to be EV-ready and all new residential homes to be equipped with the infrastructure needed to install EV charging stations.[44]

Embodied energy increasingly shapes global CO_2 emissions

Construction accounts for 24 percent of global raw materials removed from the earth.[45] As the energy performance of buildings improves, and construction and renovation accelerate, embodied energy rises in significance. Embodied energy—energy emitted during material production, on-site construction, and final demolition and disposal—is a scope 3 (indirect) emission and a growing challenge in cities around the world.

REDUCTION OF EMBODIED ENERGY IS AN IMPORTANT COMPONENT OF ACHIEVING THE FULL POTENTIAL OF TRULY ZERO-CARBON BUILDINGS.

As buildings emit less during operations, embodied energy's contribution to a building's lifetime emissions increases. In most cities, embodied energy represents between 10 and 20 percent of buildings' carbon footprint—but for cities aiming for zero-carbon buildings, such as Cape Town, South Africa, and Vancouver, Canada, embodied energy has the potential to reach 50 percent.[46] While reduced emissions overall is a sign of progress, some of the measures taken to reduce operational emissions (for example, increased insulation) may result in higher embodied carbon emissions than in a conventionally performing building. Reduction of embodied energy is an important component of achieving the full potential of truly zero-carbon buildings.

The large impact from construction materials reinforces the importance of energy labels. Environmental product declarations (EPDs), prepared by a manufacturing firm and assessed by third parties, detail the life-cycle analysis impact of building materials such as insulation, steel, metal panels, or wood products. Energy-label regulations typically fall under the authority of national governments, but multiple sectors can contribute to efforts to better disclose the environmental impact of materials. These efforts, along with continuing innovation to develop low energy–intensive building materials, have the potential to address CO_2 emissions outside the typical scope of current policies and codes.

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THE ROLE OF BUILDING ENERGY CODES IN ENERGY AND ECONOMIC TRANSFORMATION

2

Governments at all levels, from city to national, deploy numerous tools ranging from mandates to incentives to achieve public goals around carbon reductions and resource efficiency. Building codes, or minimum performance standards, are just one of the tools that have been developed. They originated with a focus on minimum standards for health and safety and have expanded to incorporate a focus on energy.

The original building codes, dating back to 1760 BC, consisted of consequences for building failure.[47] The first modern building-code efforts shifted focus to how to safely construct a building, addressing fire prevention in response to large urban fires in London and Chicago. Over time, efforts have expanded to address general safety and sanitation for tenants.

With the challenges of meeting urban energy needs and the rapidly rising global threat from climate change, energy is increasingly incorporated into building codes. The most up-to-date energy codes can create large benefits, reducing a building's energy consumption up to 70 percent compared with a similar base-case building[48] and generating large energy savings, estimated at $126 billion in the United States from 2010 to 2040.[49]

CLOSE TO 70 PERCENT OF GLOBAL BUILDING ENERGY USE IS NOT COVERED BY MANDATORY CODES OR STANDARDS.

Base building energy codes are foundational

Mandated building energy codes can reduce the carbon and energy used by newly constructed and renovated buildings across cities and can cover a wide variety of building types, including residential, commercial, institutional, and industrial. Building energy codes typically include requirements for the building envelope, mechanical systems or equipment, water-heating systems, lighting, and electrical power. Best practice is to refresh the code every few years to increase performance.

Multiple organizations have created base codes. Codes can be based on ASHRAE 90.1 (created by the American Society of Heating, Refrigeration and Air-Conditioning Engineers), the International Energy Conservation Code (IECC) requirements (created by the International Code Council), or another base code. ASHRAE 90.1 covers the design and construction of all buildings except low-rise residential, and it sets requirements for new buildings, new portions of buildings, and new equipment or systems within existing buildings. IECC incorporates ASHRAE 90.1 and covers all building types and new construction, additions, remodeling, window replacement, and repairs of buildings. These codes are updated every three years and the updates are subject to a cost-effectiveness evaluation before US states adopt the code. The EU Energy Performance of Buildings Directive is another well-known example and requires member countries to set minimum energy performance requirements for new buildings, major renovations of existing buildings, and replacement or retrofit of existing buildings; these standards are meant to optimize costs, both in terms of building investment and societal benefits of energy efficiency.

Authority for adoption of base energy codes falls to different governmental levels—national, state, or city—in different parts of the world, though national or state authority is most common. Even when cities have the authority to adopt codes, national or state governments often provide guidance.

Despite differences in adoption of code, in most jurisdictions in the world, cities are primarily responsible for enforcing building energy codes and can work to advocate for building energy code implementation at the national or state level.

From 1992 to 2012, building energy codes helped save 6 to 22 percent of EU countries' annual building energy consumption. In the United States, they saved 106 million tons of oil equivalent and more than $44 billion.[50] The benefits extend beyond established markets. Code implementation in the coastal state of Gujarat, India, could reduce building electricity use by 20 percent. In the city of Jaipur in north central India, codes could lead to energy savings of 17 to 42 percent annually based on different building types.[51] Throughout India, investments in energy efficiency, encouraged by code mandates, would generate $14 billion a year.[52]

As global demand for built-out floor space and buildings continues to increase, codes to regulate the energy supply and consumption of these new buildings are a critical lever to dampen and ultimately eliminate CO_2 emissions stemming from those buildings.[53] As mentioned earlier, close to 70 percent of global building energy use is not covered by mandatory codes or standards. Extrapolating this trend, more than 100 billion square meters of new floor space over the next 40 years would not be covered by building codes[54]—suggesting that there is a need for not only more codes but also other efforts, such as incentives for low-carbon buildings and development of appliance standards, to address energy use.

Urgency to adopt ambitious codes is increasing

The timing of code implementation is of great significance. While the world is projected to double its current global building stock by 2050, roughly 60 percent of this new construction is expected to take place in approximately the next 20 years, and two-thirds of it is expected in countries that do not have mandatory building energy codes.[55] If these buildings are designed to current standards, it will be extremely difficult to meet the targets set in the Paris Agreement. Adding to the challenge, the expected global growth in the need for indoor cooling is expected to rise exponentially—with demand for air conditioners expected to triple by 2050.

A 10-year delay in the implementation of the high performance codes for building envelopes outlined in the Beyond 2°C Scenario, a model that shows how to limit warming to 1.75°C, would result in an additional 127 exajoules of energy demand from now to 2060 in the global building sector. This amount is equivalent to three years' worth of building heating and cooling energy consumption globally.[56]

The need to adopt ambitious codes or standards that go beyond typically mandated codes is critical. In looking at energy efficiency, if codes mandate only suboptimal performance levels rather than state-of-the-art energy-efficiency technologies, future global energy demand will increase by approximately 33 percent by 2050 compared with a potential 45 percent decrease if best-practice technologies are mandated and adopted.[57]

Ambitious energy standards, notably the ZERO Code and Passive House, as well as net-zero certifications from LEED and the Living Building Challenge, greatly exceed local code requirements. Passive House has strict requirements for energy efficiency, creating ultra-low-carbon buildings. The recently released ZERO Code from Architecture 2030 addresses all carbon from ongoing building operations, building off of the existing ASHRAE code and then linking directly to energy supply.

Green building standards broaden impact

Green building certifications—voluntary standards that individual buildings can choose to pursue—typically go well beyond energy codes. These rating and certification systems cover a range of building aspects, from energy to materials to transportation, and they offer sightlines to what more ambitious codes may be able to deliver in the future—decarbonization of the grid, clean transport options, a reduction in embodied carbon, and ultimately zero-carbon buildings. (For a list of seven leading green building codes, see sidebar, "Green building certifications and standards.")

Indeed, adherence to green building certifications serves to set leaders apart from overall building stock; today, just 1 to 7 percent of US cities' newly constructed commercial buildings qualify. In contrast, mandatory codes for larger commercial buildings above a certain square footage threshold can reach more than 70 percent of newly constructed building stock.[58] These leadership certifications serve to connect buildings to broader impact on urban carbon, push for energy reductions in buildings beyond what code mandates, and show regulators that the market is ready for more ambitious codes.

The BREEAM standard, established in 1990 in the United Kingdom, was the first green building standard. BREEAM started with a standard for offices in 1990 and gradually grew to include more building types and more stringent and wide-reaching recognition. The world of voluntary certifications has grown considerably in recent decades. Cities around the world have used green rating standards as municipal targets or as requirements for large buildings. For example, Zurich encourages all municipal buildings to be constructed to the Minergie standards, a label supported by the local canton governments, and the City of Sydney recently proposed an amendment to require all new or refurbished office buildings larger than 1,000 square meters to have a minimum of 5.5 out of 6 stars under NABERS Energy, a federal rating system.[59]

Green building certifications often address holistic performance beyond the energy efficiency of a building. Many include requirements for low-carbon transportation to the building (e.g., LEED), a sustainable location of the building (e.g., Living Future), low-carbon energy sources (e.g., ZERO Code), low embodied energy from materials used in construction (e.g., EDGE), or smart management of the building (e.g., BREEAM).

The energy embodied in the materials used is a growing area of focus in standards, with a number of certifications including embodied energy or materials as a new category in new versions. CO_2 emissions from building materials are more difficult for individual cities to address, as the extraction and manufacturing of the materials often occur in other locations—creating the need for cities to push for cross-jurisdictional collaboration to better address this issue.[60]

Green building certifications and standards

There are many green building standards and certifications in the world, serving a variety of regions or setting different goals for low-carbon and healthy buildings. Here are some examples of prominent green standards from around the globe. They are in rough order from those that focus exclusively on energy to those that incorporate broader sustainability topics.

1. PASSIVE HOUSE

The Passive House building standard, developed in Germany in 1996 by the Passive House Institute, focuses on maximizing natural-energy gains, minimizing energy losses through building design, and attaining a quantifiable comfort level. The standard requires buildings to be built in accordance with five science-based principles: continuous insulation, an air-tight envelope, high-performance windows and doors, balanced heat- and moisture-recovery ventilation, and solar-gain management. Passive House certifications cover both new and refurbished buildings of any type and size. More than 60,000 Passive House buildings are in existence worldwide, with 14,000 officially certified.

2. ZERO CODE

The ZERO Code, created by Architecture 2030, is a new standard that recognizes buildings that achieve net-zero carbon emissions. Released in 2018, the standard integrates energy-efficiency requirements with on-site or off-site renewable energy to reach net-zero CO_2 emissions for new commercial and mid- to high-rise residential buildings. The ZERO Code uses ASHRAE 90.1-2016 for its energy efficiency-requirements but can be adapted for use with any other existing standard, allowing it to be implemented anywhere that has a code.

3. EDGE

EDGE, a green building standard launched by the International Finance Corporation in 2012, was originally developed to regulate new construction in developing countries. It requires buildings to reduce resource intensity in energy, water, and embodied energy in material by at least 20 percent. With the goal of identifying systems and solutions that work best for local climates, EDGE provides free software to help individuals and governments identify the most cost-effective ways to build green. To receive certification, a building must be inspected by a licensed service provider. EDGE is currently used in 140 countries and covers more than three million square meters of floor space.

4. BREEAM

The Building Research Establishment Environmental Assessment Method (BREEAM) sets standards for the environmental performance of all new and refurbished buildings in participating regions. Launched in 1990 in the United Kingdom, the standard sets requirements in a number of categories, including land use, energy, water, health and well-being, transport, materials, waste, and management. Buildings under consideration for BREEAM certification must be approved by licensed assessors, who complete both design-stage and post-construction assessments. The assessors rate and certify buildings on the following scale: Unclassified, Pass, Good, Very Good, Excellent, and Outstanding. Used in 77 countries, BREEAM has awarded more than 565,000 certifications to date.

5. LEED

The Leadership in Energy and Environmental Design (LEED) green rating system is the most widely used globally and can be applied to all types of building, community, and home projects. It provides guidance on design, construction, operations, and maintenance. Launched in 2000 by the US Green Building Council, LEED awards points across nine categories: integrative process, transportation and location, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor air quality, innovation, and regional priority. Buildings can earn one of four LEED rating levels—Certified, Silver, Gold, or Platinum—based on the number of points awarded. Today, more than 165 countries and territories use the LEED guidelines or certifications, and more than 93,000 projects are participating worldwide. LEED also has designations for neighborhoods and cities and a new net-zero certification for buildings.

6. LIVING BUILDING CHALLENGE

The Living Building Challenge, run by the International Living Future Institute, promotes structures that are restorative, regenerative, and integrated with local ecology and culture. Launched in 2006, the standard covers building performance in seven categories: place, water, energy, health and happiness, materials, equity, and beauty. Buildings are certified based on actual, rather than anticipated, performance over 12 months. The Living Building Challenge currently encompasses about 380 registered projects, 73 of which are officially certified, in 23 countries.

7. WELL BUILDING STANDARD

The WELL Building Standard, launched by the International WELL Building Institute in 2014, works with other green building standards to develop buildings that are both low carbon and optimized for human health and well-being. The standard evaluates buildings in seven core areas: air, water, nourishment, light, fitness, comfort, and mind. Buildings can earn a Silver, Gold, or Platinum certification based on the number of points earned. More than 950 buildings in 35 countries are registered or certified by WELL, accounting for nearly 200 million square feet.

THE SUCCESSFUL IMPLEMENTATION OF CODES REQUIRES ONGOING PERFORMANCE MONITORING AND CODE REFINEMENT.

Compliance and performance tracking deliver on building energy codes

A well-written energy code can only deliver substantial urban benefits with widespread adoption and compliance. Building after building must incorporate the specifics into design and construction. It is a test of scale for both the government and the many organizations that design and construct buildings—with significant education and technical expertise needed. As such, compliance is a key challenge facing most cities across the globe.

Overall, global trends regarding code compliance are not well understood—largely because data on compliance does not exist in most regions. Where data does exist, compliance is still a challenge because it typically requires capability and capacity at the government level aligned with education and outreach to the architecture, engineering, and construction (AEC) industry. Indeed, effective compliance starts with clear rules that are well understood by compliance officials and the industry, and then incorporates plan reviews and site visits. Delivering this level of engagement and ongoing education is a challenge in many markets, especially given the many other priorities fighting for the attention of governments, many of which are chronically understaffed.

Compliance rates differ significantly among countries and even among regions within countries. In the United States, for example, some states—many of which hold authority for code adoption—have compliance rates in the low double digits, while others see rates near 100 percent.[61] Meanwhile, thanks to a robust enforcement system, China is one of a few middle-income markets that have high compliance rates of around 80 percent in large cities.[62]

A broader concern is the real-world performance of buildings even as they are "built to code." Performance can fall short of intended compliance as a result of unanticipated design, construction, or material performance flaws, as well as poor management of the building in operation. For example, a simulated model can predict that attic insulation will generate annual savings of 50 percent, but actual savings can be substantially lower, potentially at just 9 percent a year.[63] The successful implementation of codes requires ongoing performance monitoring and code refinement.

Local energy-use tracking mechanisms such as benchmarking ordinances, which require existing buildings to measure their energy use and often to release the data publicly, can serve as a proxy for cities to assess overall energy performance. While operating outside of the traditional compliance function, data disclosure and benchmarking requirements may lead directly to carbon reductions. For example, if energy performance benchmarking tools were available for hotels, commercial buildings, retail buildings, and hospitals in Indonesia, the Philippines, Thailand, and Vietnam, these countries could see estimated savings of 540 million gigajoules of energy and 7.9 million metric tons of CO_2 over five years.[64] Similarly, data from select C40 cities suggest that data reporting and disclosure, through benchmarking, audits, and energy performance ratings, drove 17 percent of all emission reductions.[65] These benefits are strong, but they do not replace initial compliance, serving instead as a late but helpful addition to buildings that already exist.


kokouu/iStock

MATCHING STRATEGIES WITH MARKETS AND PATHWAYS

3

The strategies needed to address CO_2 emissions from buildings vary among markets across the globe, as do the entities that are best positioned to act. While the high-level vision around climate goals may be shared, implementation realities vary by market type.[***] Progress thus requires targeted strategies to reduce CO_2 emissions in cities of all types, anchored in (but not limited to) building energy codes.

This section assesses strategies for cities in established, middle-income, and developing markets and highlights examples of cities and buildings that have made progress in reducing building-related CO_2 emissions. To help visualize the paths these entities have taken, highlights of Diagram 1 are incorporated.

*** The markets defined in the report follow the World Bank income classifications. “Established market” corresponds to high-income countries, “middle-income market” corresponds to the high-middle-income countries, and “developing market” corresponds to lower-middle-income countries. Source: World Bank Group, “World Bank Country and Lending Groups,” accessed August 1, 2018, https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

CURRENTLY, LESS THAN 1 PERCENT OF EXISTING BUILDING STOCK UNDERGOES RENOVATION EACH YEAR.

Established markets: The cutting edge of building technology and deep conservation efforts

A majority of the buildings in cities in established markets—including Poland, Switzerland, the United Kingdom, and the United States, each of which is profiled at the city or building level in this section—are already built today,[66] and CO_2 emissions per capita in these cities significantly exceed the global average. The majority of developed countries have building energy codes in place, and overall building energy consumption has remained stable for the past 10 to 15 years.[67] But global carbon goals cannot be met without substantial reductions in energy use. The base for action includes faster retrofit cycles and increased energy-efficiency requirements for existing buildings, zero-carbon energy codes for new construction, and a transition to an all-electric future.

Currently, less than 1 percent of existing building stock undergoes renovation each year, driving energy-efficiency improvements between 10 and 15 percent within buildings.[68] This progress falls short of what is needed to limit temperature rise to 2 degrees Celsius or less. To meet the Paris Agreement goals, established markets will need to increase renovation rates to 3 percent each year by 2040.[69] Mandates and fiscal incentives for faster retrofits can accelerate renovation rates in these cities. Many cities require efficiency upgrades not just through renovation permit applications but also through time-of-sale and lease statutes that require necessary upgrades before a property can change hands.

New construction is still a critical factor in these markets despite their largely established and stable building stocks. Established markets typically improve energy-efficiency codes every few years and use voluntary standards to drive innovation. The US state of California and the Canadian city of Vancouver are redefining possibilities with plans for mandated zero-net-carbon new construction. Another push for low-carbon buildings comes from the private sector through Architecture 2030's 2030 Challenge and the related AIA 2030 Commitment. To date, more than 500 firms have committed to reducing the carbon footprint of their projects to zero by 2030.[70]

The longer-term wildcard is the potential transition to an all-electric future married with transit-oriented development. While all markets have an opportunity to realize an increasingly electric future, established markets are generally the furthest along in this transition with stable electric grids and may be nearing major shifts in the electrification of the transportation sector as well as in heating for buildings.

Buildings serve as central locations in an integrated electrical grid as well as critical nodes and determinants of cities' walking and transit systems. Buildings themselves can increasingly house renewable-energy generation. In addition, as transportation fleets transition to all electric (and potentially autonomous electric), buildings and their links to transportation can both serve and use an increasingly distributed and clean grid. An all-electric future married with efficiency advances the goal of net-zero-carbon buildings by enabling for an easier transition to a building energy supply that is 100 percent renewable. Transit-oriented development further lowers CO_2 emissions related to buildings.

Building codes rely on compliance and enforcement to be effective. Established markets typically have depth of skill and experience in both the government and private sector, but compliance remains a challenge. In many established markets, local governments charge for planning permissions and inspection, which in turn can pay for the implementation efforts needed to enforce code compliance. Moving forward, cities in established markets will need to engage in continual training, data tracking, knowledge sharing, and other efforts to improve compliance and enforcement of existing energy codes. For example, the Green Mark program in Singapore uses a robust information-sharing and e-filing platform for mandatory sustainability efforts related to buildings; the platform is designed to facilitate streamlined compliance-reporting processes for builders and engineers.

Finally, energy markets are increasingly transitioning into multidirectional platforms, representing an opportunity to monetize and offer incentives for clean-energy efforts. "Negawatts," units of energy saved as a result of efficiency efforts or reductions in energy demand, can be bought and sold as units of energy "supply," creating increased value for reductions in carbon.

The following case studies highlight how cities in established markets are targeting energy and improving codes to encourage the development of low-carbon buildings as part of their larger climate-action efforts.

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CITY SPOTLIGHT

ZURICH

Switzerland

City: *0.39 million* **Metro:** *1.90 million*

City focus: In 2008, residents of Zurich voted to reduce per capita primary energy consumption to 2,000 watts a year by 2050. The vision, in line with the goals of the 2000-Watt Society, represents an effort not simply to tackle greenhouse gas emissions associated with energy generation but also to reduce primary energy demand overall, including demand that is met by renewables. To reach this goal, Zurich made commitments to sustainable building, renewable energies, mobility for the future, and community awareness.

Critical actions: Multiple levels of government have an impact on energy codes in Zurich: the national government sets the framework for energy-efficiency efforts, and the canton, or state-level government, writes the building energy codes that are applicable in that jurisdiction. The city enforces energy codes, pushing regulations to support a 2000-Watt Society and serving as an example by setting stronger targets for public buildings. Specifically, the city cultivates innovation by focusing its goals on both embodied energy and operational energy to address life-cycle emissions from buildings. The city also completes energy audits on new and refurbished buildings to ensure they perform at the expected standards. In addition to government-led action, a private organization overseen by associated local governments publishes stricter voluntary green standards—the Minergie, ECO, and SNBS standards—to propel further reductions in energy consumption. These standards are well known and accepted among private-sector actors, and many developers work toward Minergie standards in their construction efforts.

Future vision: The city aims to continue improving energy efficiency, specifically in renovations and in the development of large buildings. It also plans to continue its transition to renewable energy and to facilitate environmentally friendly modes of transport as a key energy-reduction lever, particularly by making the city center walkable.

CITY SPOTLIGHT

CHICAGO

United States

City: *2.71 million* **Metro:** *9.51 million*

City focus: In 2017, the City of Chicago pledged to meet the commitments of the Paris Agreement by reducing CO_2 emissions 26 to 28 percent below 2005 levels by 2025. This pledge builds on the city's existing climate work and recent emissions inventories showing a reduction in CO_2 emissions between 2005 and 2015.

Critical actions: With buildings accounting for 71 percent of all CO_2 emissions, the City of Chicago has a variety of initiatives to reduce building emissions. For example, the city has a mandatory building code for all building types based on the 2015 edition of the International Energy Conservation Code (IECC). It also now requires an architect or engineer to complete a compliance form as part of the permit process for new construction and to provide documentation of each project's compliance with the energy code.

Authority for building code adoption in the United States lies with local or state governments, and national standards recommend codes based on ASHRAE or IECC guidelines. In 2013, to drive reductions beyond code the City of Chicago adopted a mandatory benchmarking ordinance that requires all buildings larger than 50,000 square feet to measure energy usage, report it annually, and verify the data. The ordinance covers about 1 percent of buildings in Chicago; together, these buildings are responsible for 20 percent of citywide CO_2 emissions. Starting in 2019, the buildings will receive ratings of 0 to 4 stars, which in future years they must post publicly. Buildings covered by the ordinance reduced CO_2 emissions by 19 percent per square foot in two years.[71]

The City of Chicago also established the Retrofit Chicago Challenge, which encourages building owners to reduce energy use by 20 percent within five years of joining the program. Some projects that receive city assistance or require special approvals must adhere to the city's Sustainable Development Policy, which addresses comprehensive sustainability elements such as energy, water, transportation, and health. This policy has helped make Chicago a global leader in green roofs (nearly 5.6 million square feet) and LEED-certified buildings (roughly 180 million square feet). The policy now allows development teams to choose from a menu of strategies that can be tailored to a specific project.

Future vision: Future priorities in Chicago include a commitment to power all municipal electricity with renewables by 2025 and a proposal to expand transit-oriented development to increase walkability and use of public transport. The next update to the energy code is scheduled to go into effect in 2019. In addition, Chicago is installing a network of urban environmental sensors called the Array of Things to drive further innovation.

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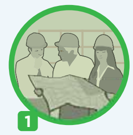
CITY SPOTLIGHT

WARSAW

Poland

City: *1.74 million* **Metro:** *3.10 million*



City focus: An economic base for a growing number of major companies, Warsaw has outlined its goals to address CO_2 emissions in its Sustainable Energy Action Plan. Most notably, in response to EU directives the city aims to reduce CO_2 emissions by 20 percent and increase the share of renewables to 20 percent by 2020. With previous efforts grounded in public transportation and district heating, the city is also enhancing building-efficiency efforts.

Critical actions: The national government in Poland, which has control over building energy codes for private-sector construction, has established mandatory energy codes for buildings in response to EU directives. The country's 2014 Energy Performance of Buildings Law regulates energy performance certificates and inspections of heating and air-conditioning in buildings. The government also created a National Action Plan aimed at increasing the number of low-energy buildings.

Although the city lacks the power to enforce all building codes, it is exploring standards for residential and public municipal buildings. Through a partnership with the Building Efficiency Accelerator, the city is working to develop housing standards for Warsaw and to construct a newly planned residential area that would follow those standards. To improve quality of life and reduce air pollution, the city is expanding its district heating system and renovating the system to upgrade performance. The city has also focused its attention on increasing low-emission public transportation options for residents. Warsaw plans to expand its second subway line and to add 130 electric buses to its existing fleet of 30, bringing the number of low-emission (electric, hybrid, and gas) buses to more than 300 in 2020.[72]

Future vision: Warsaw is experiencing rapid economic growth. As a participant in the Global Covenant of Mayors, the city has committed to take further action on climate. In future years, the city hopes to finalize new housing standards, foster efficiency in buildings, and address spatial planning and economic management of resources. Another key goal for the city is to shift from a largely coal-fired energy base to low-carbon energy sources.

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CITY SPOTLIGHT

AUSTIN

United States

City: *0.95 million* **Metro:** *2.06 million*

City focus: One of the fastest-growing cities in the United States, Austin, Texas, has set a long-term goal of carbon neutrality by 2050, in line with its C40 commitment to adhere to the Paris Agreement. As the city continues to grow, new-construction and transportation emissions will present key challenges. The city's top climate priorities are to increase the use of renewables as a portion of the energy mix and address transportation emissions.

Critical actions: The City of Austin has well-developed programs for energy efficiency in buildings, including citywide energy codes that are based on IECC standards (one of the two, along with ASHRAE, recommended by the US government) and updated every three years with input from local experts. The city also has a local green-building certification, the Austin Energy Green Building standard. Furthermore, the city-controlled energy utility currently achieves an energy mix of 63 percent renewables and nuclear, and it expects to reach 90 percent carbon free by 2027.

Other innovative programs include a new requirement for all new homes to be built solar ready, incentives for apartment buildings to include electric-vehicle charging stations, programs that provide technical assistance to developers and buildings, and efforts to engage contractors on city rebate programs for energy-efficiency retrofits. Engaging contractors with city rebate programs allows frontline workers to inform consumers of possible savings from energy-efficiency renovations.

Future vision: A vision is emerging in Austin of an all-electric future powered by renewables. As a sprawling city, Austin will focus on reducing emissions from the transportation sector, primarily through renewable energy–fueled electric vehicles and urban-plann

Tamedia New Office Building. Zurich, Switzerland.
Didier Boy de la Tour

Innovative buildings in cities in established markets

The Bullitt Center, a six-story, 50,000-square-foot office building in Seattle, Washington, was built with the intention of being "the world's greenest commercial building."[73] The building's developers met the standards of the Living Building Challenge, a certification that requires 12 months of net-zero energy, waste, and water. The building is 83 percent more efficient than traditional office buildings in Seattle and produces 230,000 kWh of electricity a year through rooftop solar panels, covering the building's annual energy consumption.[74] The building is also easily accessible by foot, bike, and public transportation, and it does not provide vehicle parking, instead offering parking for 29 bikes.[75] The owners reduced the building's carbon footprint during construction by minimizing the use of concrete, a high carbon emitter, and relying on sustainably sourced wood. The Bullitt Foundation, which owns the building, hopes the center will serve as a leadership example in the market, showing that a carbon-neutral building can be commercially viable and aesthetically stunning.

3 5 6 7

The Tamedia building, located in Zurich, was designed to be carbon neutral. The seven-story office building is built primarily of wood, with no steel or concrete reinforcements, to reduce embodied CO_2 emissions from construction materials. The building also features large glass windows to optimize natural lighting. Other features include a double facade to act as a buffer against climate conditions and as a natural ventilation system, and the elimination of fossil fuels through use of a groundwater heating and cooling system.[76]

6 7

The Tribe Apartments, located in Manchester, United Kingdom, received a BREEAM Outstanding classification. The three-building complex was also named the Best Residential Scheme in the BREEAM 2017 Awards for its sustainable features. The 13-story buildings, originally built in 1950, were empty for 15 years before the recent renovation. The renovation included upgrading the insulation, adding glazed facades to optimize daylighting, using LED lighting and biomass boilers, and limiting construction waste and embodied energy through maximized use of the existing features and structure.[77] The renovation reduced water consumption by 25 percent and CO_2 emissions by 65 percent compared with a newly built apartment.[78] The apartment buildings are a 10-minute walk from the city center, creating a walkable urban environment for residents.

6 7

TODAY, THE MAJORITY OF MIDDLE-INCOME COUNTRIES DO NOT HAVE WELL-DEVELOPED MANDATORY ENERGY CODES.

Middle-income markets: Developing and scaling carbon efforts amid increasing construction and rising incomes

Cities in middle-income markets—including China, Malaysia, Mexico, and South Africa, each of which is profiled at the city or building level in this section—are experiencing dramatic increases in new-building construction and building energy consumption.[79] This wave of construction will strengthen these cities' economies—but from a carbon standpoint, the next few decades are critical. Today, the majority of middle-income countries do not have well-developed mandatory energy codes. The primary challenge facing cities in middle-income markets, therefore, is to support growth while quickly developing and implementing energy codes for new construction. At the same time, these cities must foster energy-efficiency improvements in end-use appliances and increases in local capacity for code enforcement.

To start, middle-income markets need to take rapid steps to establish and implement mandatory codes for new construction to address anticipated increases in floor space. Initiatives to move toward lower-carbon buildings are emerging. For example, the Colombia Green Building Council helped the City of Bogotá, Colombia, integrate the national regulation for building construction into a local regulation. Dozens of international and Chinese architecture firms have signed the China Accord, a commitment to plan and design cities and buildings in China to zero- or low-carbon standards. These types of actions need to accelerate in the coming years to avoid locking in decades of high carbon usage in future construction.

Related concerns include the anticipated increase in demand for electricity within buildings, as well as the need for strict energy-efficiency standards for appliances and end-use equipment. On average, rising incomes (in combination with other factors) result in an expected 1.9 percent increase in electricity use per year.[80] Appliance standards are often regulated at the national level, not local, leaving cities to support and even advocate for national-level policy change—but likely not lead it.

Of particular importance is the anticipated increase in air-conditioning use in middle-income countries, many of which are in hot climates and are expected to experience greater temperature extremes in the coming years. In China, electricity demand for cooling alone is projected to exceed the total electricity demand of Japan by 2040.[81] To achieve the maximum technical reductions in

TO ACHIEVE THE MAXIMUM TECHNICAL REDUCTIONS IN BUILDING ENERGY CONSUMPTION, MIDDLE-INCOME COUNTRIES MUST DEPLOY ENERGY-EFFICIENCY APPLIANCE STANDARDS IN CONJUNCTION WITH ENERGY CODES.

building energy consumption, middle-income countries must deploy energy-efficiency appliance standards in conjunction with energy codes.

Compliance in these countries will remain a significant challenge; in the face of competing priorities, many cities lack resources for robust inspection practices or industry education. These cities need new efforts and novel solutions for increasing compliance. For example, design principles that promote passive maintenance of comfortable indoor air temperatures without air-conditioning (or with less air conditioning) could be an important tool in discouraging individual building users from adopting unsustainable building energy and appliance-use practices as incomes rise.[82] These design principles would need to be communicated in regionally specific vernacular to ease compliance for architecture, design, and engineering firms.

The opportunity to strengthen the resilience of a city's building stock in case of natural disaster while also upgrading efficiency standards may be a salient entry point in cities that have weak or nonexistent codes. Combining disaster-resilience efforts with energy-efficiency codes has become an increasingly important policy initiative in many middle-income and developing markets.[83]

The following case studies highlight how cities in middle-income markets are targeting energy and improving codes to encourage the development of low-carbon buildings as part of their larger climate-action efforts.

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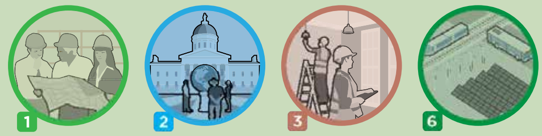
CITY SPOTLIGHT

GUANGZHOU

China

City: *14.50 million* **Metro:** *25.00 million*



City focus: The third-largest city in China, Guangzhou has taken significant action to reduce CO_2 emissions and has committed to peaking CO_2 emissions by the year 2020. Facing a growing population and rising demand for energy, the city released a Low Carbon City Implementation Plan to reduce greenhouse-gas emissions and included CO_2-reduction goals in previous five-year plans. City actions up to this point have focused on improving building efficiency and reducing transport emissions. The city is currently focused on reducing water, air, and soil pollution.

Critical actions: The national building efficiency code in China, the Design Standard for Energy Efficiency of Public Buildings, sets building-envelope and HVAC regulations for all nonresidential buildings. Three separate regulations, based on climate zone, cover residential buildings. The national government also sets separate regulations for lighting and room air conditioners within buildings. The city enforces these regulations with the help of local construction agencies, which coordinate enforcement, and third-party inspectors, who carry out enforcement during the design and construction phases.[84]

The city has also engaged in a number of energy initiatives over the years to reduce energy use among buildings and to better link buildings to transportation in the city. Most recently, the city implemented a mandate that all large public institutions, such as hospitals and schools, conduct energy audits and install energy-efficiency upgrades. The mandate covers 206 institutions and requires a 20 percent reduction in energy demand per unit of floor area.[85] Between 2012 and 2015, 31 energy-efficiency projects cut power consumption by 21,000 megawatt-hours and reduced CO_2 emissions by 12,000 tons.[86] The city has also engaged in public service announcements during peak demand periods to encourage residents to reduce consumption. Finally, the city created a rapid-transit corridor for buses in a highly dense area of the city to reduce emissions. The corridor now serves as a central node in a multimodal transport network and links bus stations directly to adjacent buildings and bike parking. The project has saved an estimated 86,000 tons of transportation CO_2 emissions to date.[87]

Future vision: A coastal city identified as one of the world's most susceptible to climate change,[88] Guangzhou will continue working toward its goal of peaking CO_2 emissions by 2020. The city plans to expand its urban rail transit system to 520 kilometers, connecting Guangzhou to nearby cities and linking the downtown with new districts.[89]

City of Cape Town, Bruce Sutherland

CITY SPOTLIGHT

CAPE TOWN

South Africa

City: *0.43 million* **Metro:** *3.74 million*

City focus: Cape Town, South Africa—a member of the Global Covenant of Mayors—has raised its targets for reducing CO_2 emissions and, along with other C40 cities, has committed to carbon neutrality by 2050. Cape Town is working toward these targets in collaboration with C40, Sustainable Energy Africa, and three other major South African metropolitan areas to innovate and scale solutions. In addition to these goals, Cape Town aims to mitigate the crises it is currently facing, including severe drought and blackouts.

Critical actions: In South Africa, the national government holds authority over energy codes, transportation, and large-scale renewable energy supply, but Cape Town has made significant efforts on a local level. In 2013, the national government added amendments to the building code to include mandatory energy-efficiency requirements for all buildings. The city is responsible for enforcing the code, which it does by requiring all building plans to be approved by an architect or engineer.

With support from the C40 South Africa Building Program and in collaboration with other large cities in South Africa, Cape Town is developing its own municipal regulatory policy to accelerate its path to net-zero-carbon buildings. This approach builds on the Green Building Council South Africa's efforts to serve in a leadership role and to promote energy efficiency in buildings through voluntary Green Star South Africa sustainable-building certifications.

The city is also engaged in litigation with the national Ministry of Energy to gain permission to enter into power-purchase agreements for large-scale solar, wind, and other renewable energy. Local-government efforts also include large-scale electricity-saving campaigns emphasizing consumer cost savings, a public-private Energy Efficiency Forum to promote energy conservation in commercial buildings, efforts to improve energy access in low-income areas, and a Transit-Oriented Development Strategic Framework to restructure the city spatially and address the apartheid legacy of spatial inequality and urban sprawl.

Future vision: Future initiatives in Cape Town support the city's goal of becoming carbon neutral by 2050. Specifically, the city aims to improve energy performance of buildings, invest more in renewable energy, and improve public transportation. The city also wants to undertake spatial transformation, reinforced through transit-oriented development to intensify and diversify development within particular zones to avoid new sprawl.

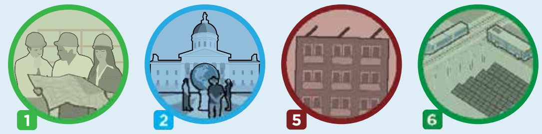
jose carlos macouzet espinosa/iStock

CITY SPOTLIGHT

MEXICO CITY

Mexico

City: *8.85 million* **Metro:** *21.20 million*



City focus: Mexico City has set an interim goal to mitigate 10 million tons of CO_2-equivalent emissions by 2020. To reach this goal, the city created the Climate Action Program, which details seven strategic priorities and 102 actions to address environmental concerns. The seven strategic priorities include urban and rural energy transition, containment of urban sprawl, environmental improvement, sustainable management of natural resources and biodiversity, resilience, education and communication, and research and development. The city's ultimate vision is to become carbon neutral by 2050, in line with its C40 commitment to adhere to the Paris Agreement.

Critical actions: Given that electric power is Mexico City's second-largest source of CO_2 emissions (after transportation), one of the city's top priorities is improving the energy performance of its buildings. The city is working to adopt improvements to the energy-efficiency features embedded in its construction code for new and retrofitted buildings. Improvements are based on the energy conservation code endorsed by the national government, which serves as a guide for Mexican states to implement their own codes and regulations.

In addition to the mandatory construction code, the city implemented the voluntary Sustainable Buildings Certification Program, which offers certifications for building owners and also for tenants in leased portions of buildings. The inclusion of tenants in the certification program addresses a common challenge of split incentives for energy-efficiency improvements. Working with the private sector, the Green Building Council Mexico has helped prompt low-carbon construction, giving Mexico City the highest concentration of LEED-certified buildings in Mexico,[90] although LEED penetration in the city is still relatively small.

Other innovative efforts include a local bylaw requiring solar water-heating systems in new construction to address energy-demand and air-quality concerns (as a function of averting on-site diesel generation for water heating) and energy audits and retrofits for public buildings. The city has completed audits and retrofits on four public buildings, and it has completed audits with plans for future retrofits on an additional 15.

To supplement efforts to reduce building energy consumption, the city is implementing urban-planning policies and expanding public-transportation options to encourage the use of public transport and reduce overall energy demand in the city.

Future vision: Mexico City has achieved close to 70 percent of the goals set by its Climate Action Program. Its next steps are to complete the rest of the initiatives before 2020. The city also hopes to complete more energy audits and retrofits on public buildings to continue to demonstrate best practices for energy efficiency.

The Pearl River Tower. Guangzhou, China.
REUTERS/Bobby Yip

Innovative buildings in cities in middle-income markets

Antiguo Palacio del Ayuntamiento, located in Mexico City, was the first historic building in Latin America to receive a LEED: Existing Building Operations and Maintenance (LEED: EBOM) certification. Originally built in 1527, the Antiguo Palacio del Ayuntamiento is a four-level, 96,649-square-foot government building. Its original structure included efficient features such as thick walls and central courtyards that provide natural lighting and ventilation, but the building also benefited from renovations to improve its operations and sustainability features, and it achieved LEED Platinum certification in 2018. Additional features include white waterproof material on the roof to reduce the heat-island effect, a commissioning plan to ensure that HVAC and lighting equipment continue to perform efficiently, and diversion of more than half of all waste from consumables. The building's location also enables 89 percent of users to reach it without driving.[91]

5 6 7

The Pearl River Tower, a 71-story commercial skyscraper in Guangzhou, China, is certified LEED Platinum. When completed in 2011, the building was considered China's greenest building and first green skyscraper.[92] Designed to maximize use of renewable energy, the building is positioned to make optimal use of the solar path through natural lighting and energy from solar panels. The design of the building also directs wind to a pair of openings on the floors housing mechanical equipment, where it pushes turbines to generate energy for the building. The building also includes a double-skin curtain wall, a chilled ceiling system, and under-floor ventilation.[93]

5 6

Shophouses, a particular type of building in Penang, Malaysia, operate with low carbon intensity in part by maintaining their vernacular architectural features. Both residential and commercial in nature, these buildings were typically first built in the 19th and 20th centuries. In addition to keeping the key design elements of earlier times, such as arches and stylized columns, shophouses incorporate passive-cooling and solar-shading design features such as large open spaces, shuttered doors, and sheltered pedestrian walkways. For example, one shophouse that was studied in George Town, the capital of the state of Penang and a UNESCO World Heritage Site, remained at a temperature the occupants found comfortable during the day without mechanical ventilation. The studied home had clay brick walls to create a high thermal mass and Chinese-style air vents, among other features.[94]

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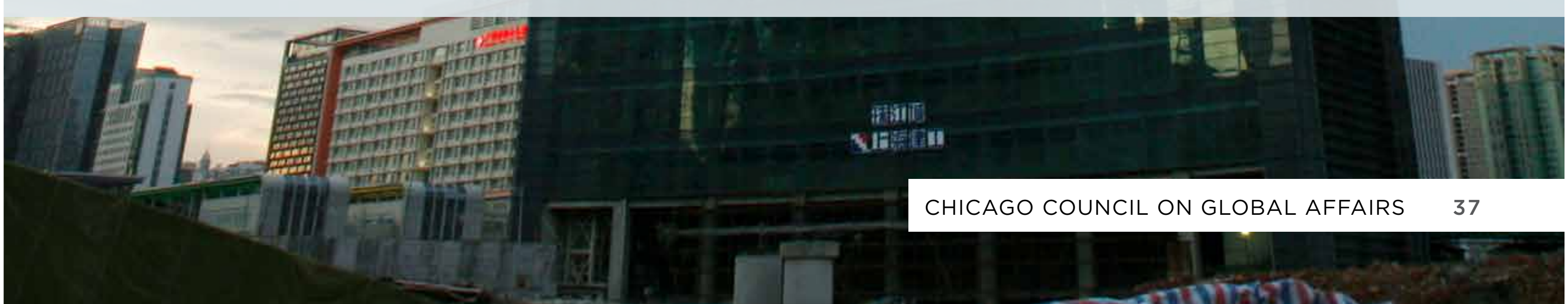


Developing markets: Establishing foundational codes with links to resilience and appliances

Cities in developing markets—including Ghana, India, Indonesia, and Tanzania, each of which is profiled at the city or building level in this section—are changing rapidly and are expected to dominate global building construction from 2030 to 2060. Currently only a few of these countries have building codes in place. The broader challenges are significant, given that across the globe, an estimated 1.1 billion people lack access to electricity and approximately 2.5 billion continue to rely on biomass, coal, or kerosene as their primary cooking fuel.[95] Developing markets must create stronger energy infrastructure and access while also constructing billions of square feet of new buildings. Cities and their home nations will need to create initial energy codes and compliance mechanisms linked to expanded clean-energy systems as quickly as possible. They will also need to pursue actions that address building-energy use outside of codes.

Developing markets face a unique challenge: they need to develop base energy codes to both avoid locking in decades of high carbon usage in new construction *and* to address concerns about access to modern energy sources. In other words, the market-wide challenge is to ensure increasing levels of energy access to improve the standards of living for millions of people who currently lack access to modern energy sources—and to do so in a way that takes advantage of overall efficiency efforts and renewable energy as well as conservation efforts among high-consuming segments of the market.

From 2015 to 2060, developing markets will see billions of meters of growth in floor space, the majority of which is not slated to be covered by building energy codes. Even where codes exist, however, millions of urban residents live in informal settlements, beyond the reach of typical urban infrastructure, government services, and regulations. Developing building energy codes will be critical to capture the bulk of new construction, as will efforts to address both energy access and energy use outside of codes.

As with middle-income markets, the opportunity to enhance the resilience of a developing-market city's building stock in the face of natural disasters, while also upgrading efficiency standards, may be an effective entry point for developing regulations around code in cities that currently have none. Specifically, for places in which portions of the population are already facing climate change–related weather risks, the policy principle of "build, back, better" is increasingly important. Reconstruction efforts after a natural disaster can provide an opportunity to reconstruct safer, more efficient, and more resilient building stock for displaced populations.[96]

Noncode pathways to addressing energy use will be critical in the years to come—not only in markets without building energy codes but also in markets with codes. One pathway is to directly address the energy efficiency of key appliances that shape overall household or building energy demand. This often requires action from other levels of government beyond the city; in many

FROM 2015 TO 2060, DEVELOPING MARKETS WILL SEE BILLIONS OF METERS OF GROWTH IN FLOOR SPACE, THE MAJORITY OF WHICH IS NOT SLATED TO BE COVERED BY BUILDING ENERGY CODES.

developing nations the national government sets the code. Cities would benefit from coordination on the specifics of the code and from technical resources to enforce it.

Increasing the efficiency of household appliances has significant potential for broader benefits. For example, electric and efficient appliances have a direct impact on indoor air quality, which in many countries is affected by the use of biomass fuels for cooking. As global temperatures continue to rise, access to “coolth,” or a pleasantly low temperature, will be a growing need in developing markets. Of the 2.8 billion people living in the hottest areas of the world, only 8 percent currently own air conditioners; as incomes rise, this percentage is expected to increase dramatically. The two countries in this market with the highest expected growth are India and Indonesia, which along with China are expected to account for half of all global cooling demand by 2050.[97] Highly efficient air conditioners will become increasingly important to offset this significant growth in electricity demand. So too will regionally relevant design principles that rely on vernacular building materials and styles to passively regulate indoor air temperatures, helping reduce demand for air-conditioning.

As in markets with existing codes, enforcement will be a challenge. The integration of locally relevant vernacular design principles, along with tools to train relevant stakeholders on low- and no-carbon strategies, can help foster compliance. In addition, as cities implement initial codes, funding and financing support for the up-front costs of building to code can improve compliance.

The following case studies highlight how cities in developing markets are targeting energy and improving codes to encourage the development of low-carbon buildings as part of their larger climate-action efforts.

Goldcoast Photography, Accra

CITY SPOTLIGHT

ACCRA

Ghana

City: *1.60 million* **Metro:** *4.30 million*

City focus: As one of the fastest-growing cities in the world, Accra faces significant climate and environmental concerns. The city anchors its climate goals in smart, resilient, sustainable planning to address the rapidly growing population and 10 percent annual growth in energy demand.[98] Specifically, results from a greenhouse gas emission inventory, completed as part of a C40 commitment, identified three top climate priorities for the city: waste, transportation, and energy.

Critical actions: Ghana's national government is responsible for building codes, which include requirements on energy efficiency. At the city level, to further encourage the transition to a sustainable and resilient city, Accra has established a number of partnerships. The World Bank is helping Accra use the EDGE certification to better assess the energy efficiency of buildings and identify possible pathways to improve energy efficiency. In addition, the EU Energy Initiative Partnership Dialogue Facility has partnered with the Accra Metropolitan Assembly to provide technical and financial assistance for the development of an energy-efficiency strategy for public buildings. As a beginning step for energy efficiency, the city government has completed two demonstration projects on public buildings to showcase the feasibility of low-carbon construction.

Future vision: Accra hopes to expand beyond existing initiatives in the coming years. A top goal for the city is to build capacity for the assessment of energy efficiency within building plans and existing buildings. After creating the capacity to assess buildings, Accra aims to provide incentives for buildings constructed with low-carbon techniques to help private organizations address concerns about up-front capital. Finally, the city aims to reduce air pollution by expanding public transportation options, specifically bus rapid transit. These efforts will feed into Accra's C40 commitment to be carbon neutral by 2050.

adiartana/iStock

CITY SPOTLIGHT

MAKASSAR

Indonesia

City: *1.30 million* **Metro:** *2.50 million*

City focus: Top sustainability priorities for Makassar include addressing concerns around rising sea levels, supporting the ongoing sustainable development of island territories into more concentrated population centers, and accommodating the energy needs of a rapidly growing urban population and urban built environment.

Critical actions: Rapid growth and underpowered electricity operations in the region mean that electricity cuts are common and energy stability remains a primary concern. To mitigate these concerns while building energy efficiency, Makassar has taken several actions in recent years to enact mandated standards for new building construction. Since 2014, the city has required that all new development helps offset new energy demand by installing supplemental on-site generation, powered either by solar or by gas and diesel. This regulation applies to all new construction and to existing buildings undergoing renovation or expansion. Some builders and developers are choosing to deploy renewably powered generation on-site to fulfill the energy supplement requirement, but solar panels are cost prohibitive for many in Makassar; panels are typically imported from Singapore or Malaysia. The government has initiated clean-energy efforts in its own municipally owned building stock by installing rooftop solar panels and by engaging in conservation protocols wherein electricity is turned off each day at 6 p.m. in applicable buildings. In 2016, the city issued a regulation requiring that newly constructed buildings incorporate green-roof facilities or surrounding green space to encourage passive regulation of building temperature—a particularly important move given the region's hot climate and the widespread use of air-conditioning to maintain comfortable indoor temperatures.

Future vision: Makassar considers itself to still be developing and is concerned with meeting the needs of ongoing urban development and population growth. As such, the city is focused on ensuring that future development allows citizens to live comfortably, while also being environmentally friendly and using natural resources efficiently.

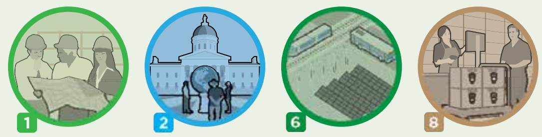
Rakesh Raja/EyeEm/Getty Images

CITY SPOTLIGHT

VISAKHAPATNAM

India

City: *2.04 million* **Metro:** *5.34 million*



City focus: The City of Visakhapatnam is facing infrastructure challenges due to large population increases, rapid industrialization, and the threat of rising sea levels. As part of a national government program, Visakhapatnam has implemented a Smart City Framework Plan to guide its development into an integrated city-region through smart business and green living. A key focus for the city is to increase resilience to climate change, because it is situated in a region likely to experience significant impact from weather events and rising sea levels.

Critical actions: Because India is expected to experience massive building growth, the national government launched the Energy Conservation Building Code (ECBC) in 2007 to guide energy-efficiency regulations at the state level. States in India have the authority to adopt the ECBC into mandatory code, and Andhra Pradesh, the state in which Visakhapatnam is located, officially adopted the ECBC into state law for all large nonresidential buildings in 2014.[99] The state also offers incentives, through reductions in permit fees, to buildings that go beyond code and receive ratings from the Indian Green Building Council.[100] The role of the city is to enforce the mandatory state law, and Visakhapatnam is starting to develop mechanisms to implement and enforce the code locally. In related actions, the city has been working to expand its use of renewable energy—for example, the Greater Visakhapatnam Municipal Corporation (GVMC) is constructing floating solar farms in local reservoirs, canals, and streams, as well as deploying solar installations on the rooftops of administrative buildings and more than 140 schools in response to land constraints.[101] The city has also converted all 91,000 streetlights to LED lightbulbs—the largest LED streetlight initiative in India.

Future vision: As one of India's pilot Smart Cities, Visakhapatnam will continue to make efforts to develop both economically and sustainably. The city is in the starting stages regarding the ECBC. The city is also considering using more efficient pumps in the pump houses that support municipal water and wastewater systems.

Navi Mumbai Muncipal Corporation Office.
Navi Mumbai, India. *Suraj Jaiswar/Shutterstock*

Innovative buildings in cities in developing markets

The "Inno-native" Home in Accra, Ghana, is constructed of local materials, such as wood and adobe blocks, and without air-conditioning. Built by architect Joe Osae-Addo for his family, the home has slatted-wood screens and floor-to-ceiling windows for cross ventilation and deep overhangs for shade. Osae-Addo designed the house to be elevated three feet off the ground to allow for underfloor breezes. While the house is connected to the national grid, it uses solar panels for backup energy and water heating.[102]

2 6 7

The Luminary, an office building in Dar es Salaam, Tanzania, ushered in a new era when it was named the first LEED-certified building in the country. The 66,106-square-foot building achieved LEED Gold in February 2016. The building was designed to reduce the typical energy needed for a building of its size by blocking the sun at various angles to help both cool the space and maximize daylight. The Luminary is located within walking distance of a number of community assets and is well connected to public transportation.[103]

5 6

The Navi Mumbai Municipal Corporation headquarters, a LEED Gold–certified building, became the first government building in India to receive a green-building certification in 2014. Located in Navi Mumbai, the 33,258-square-meter building houses governmental offices. The building includes an efficient building envelope, high-performance glazing, efficient lighting and mechanical systems, solar panels, and antireflective tiles to limit air-conditioning demand. The building combines 19th-, 20th-, and 21st-century architectural styles and was intended to last for the next 200 years.[104]

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GoodLifeStudio /iStock

NINE PRINCIPLES FOR LOW-CARBON CITY ACTIONS ANCHORED IN THE BUILDING SECTOR

4

Across cities and market types, clear and rapid actions will be needed to address carbon and support economies—from construction of low-carbon buildings to accelerated retrofits of existing buildings, and from more walkable urban planning to local renewable energy production. Codes and standards driving low- to zero-carbon buildings are critical as a base in a larger effort. Although cities in different markets have distinct pathways to follow, nine shared principles can support reductions in carbon emissions from cities of all types.

1. Treat building energy codes as part of a larger transformation

Energy codes and building standards do not occur or succeed in isolation. A city with strong goals for carbon and economics must shape an all-encompassing vision—one that inspires a broader transformation in both ambition and practice. That vision must include building energy codes, but it cannot stop there. This is particularly the case in markets where consistent access to energy is a challenge and massive urbanization is underway.

Cities will need to view the development of energy codes and the transition to low-carbon buildings as part of a larger goal in a vibrant and low-carbon city; the multiple benefits of codes must be clear and paired with other actions. In all cities that were interviewed in the process of researching this report, codes were integrated in a broader vision for carbon reduction or resilience.

Cities frame their ambitions differently. In Cape Town, ongoing efforts aim to develop and begin implementing ambitious new building energy performance requirements that will build the path to a resource-efficient, carbon-neutral, and climate-resilient city by 2050 (see "City spotlight: Cape Town, South Africa"). Zurich, however, set a goal to be a 2000-Watt Society, and its initiatives to address energy use from buildings center on helping the city reduce both CO_2 emissions and primary energy use (see "City spotlight: Zurich, Switzerland"). And in Accra, the green building efforts, including government energy-efficiency projects and goals to develop incentives for low-carbon construction, are centered on the need to transition into a resilient and sustainable city (see "City spotlight: Accra, Ghana").

2. Develop ambitious and appropriate building energy codes in all markets

Too much is riding on the energy consumption and emissions of buildings to ignore the necessity of ambitious and mandatory codes. Every jurisdiction in the world needs to develop bold energy codes to drive energy efficiency and significant CO_2 reductions in buildings. The codes developed will need to cover a wide range of building types and stages, including new construction and renovations of commercial, industrial, multifamily, and single-home buildings of any size and location.

The focus on CO_2 must be consistent, but all jurisdictions do not need identical details in the codes. Low and no carbon does not and should not look the same in every market. These codes must recognize current and future renewable energy capacity, as well as the strength of both design and capability in compliance—and they will need to match local materials, infrastructure capabilities, and climates.

Ultimately, codes must be mandatory and will need to ramp up their efficiency and clean-energy requirements. Many markets build upon the ASHRAE or IECC systems, where updates occur every few years. Voluntary policies can help build up the supply of energy-efficient materials and capacity for enforcement but don't lead to the scale of mandatory codes.

National and provincial governments can contribute to these efforts by granting cities the authority to adopt more stringent codes and guiding cities with best-practice regulations to enable all new and existing developments to be net-zero-ready—or net-zero now. For example, the Ministry of Energy in Mexico endorsed an Energy Conservation Code for Buildings, but it did not issue a regulation for the nation. The ministry instead issued a document for how cities can adopt the model code into local regulations, which Mexico City and other cities have done or are currently in the process of doing. Similarly, in India, the national government launched the Energy Conservation Building Code to guide local regulations, with states holding authority to adopt the code into law and cities, such as Visakhapatnam, serving in an enforcement role once states adopt the code.

In all markets, cultural preferences around indoor air temperature, air-conditioning use, and general disposition toward energy use for lighting and appliances should be considered when developing regionally specific building energy codes and standards.[105] Codes have an opportunity to employ sustainable local design and building practices—traditional or vernacular building design and materials—to leverage passive heating, cooling, shading, and daylighting strategies.

Code development should also look ahead to new technology and market realities that may make more ambitious standards scalable faster. This includes "efficiency plus" stretch codes, which currently emphasize solar readiness, or the ZERO Code, which addresses all energy used by a building. This process also warrants additional consideration of new or emerging mass-market technologies such as widespread electric vehicle fast-charging stations or thermal storage where building cooling functions are shifted to off-peak hours—ultimately moving to full carbon reduction.

3. Implement robust enforcement and tracking mechanisms

Achieving high rates of compliance is a challenge in all market types. Many places see a performance gap between what codes are written to achieve and the actual energy use of buildings. To reach the high levels of energy savings written into codes, all levels of government need to emphasize implementation and enforcement—and collaboration is critical. The responsibility for enforcing building energy codes typically falls to the local level of government regardless of which level sets the code. The investment in enforcement will yield large benefits: one estimate suggests that each dollar spent on enforcement yields six dollars in energy savings.[106]

A key to enforcement is the inspection process. A review to ensure the initial building plans comply with building requirements can then be married with on-site inspection. In Cape Town, the city requires any building plan to receive approval from an architect or engineer to ensure initial compliance. Data from the US residential sector suggests that buildings subject to review consume no more energy than expected based on the code. Similarly, when China adopted a set of rules for inspection, compliance grew significantly in the following years.[107]

Municipal capacity: Inspectors who are well informed about local building energy codes and who are part of a sufficiently staffed team can lead to improved compliance within cities. Trainings and classes for inspectors help ensure they can accurately check a building for compliance with the codes. For example, the City of Boston hires internal staff specifically for energy code inspection, and all building-code officials must attend energy code plan review and inspection trainings.[108]

Other key actions for the city are to ensure adequate pay and monitor inspectors to avoid corruption within the inspection process. In addition, to increase capacity for inspection, cities can rely on and then manage third-party inspectors. For example, local construction bureaus in Chinese cities, such as Guangzhou, use third-party inspectors to scrutinize buildings in both the design and construction phases. The third-party inspectors must attend trainings and pass a licensing test. They are then hired by building owners and monitored by the construction bureaus.[109]

Tools: Cities can use penalties or benchmarking ordinances to help with compliance as well. Monetary fines and the withholding of building permits on noncompliant buildings can be a convincing motivator for developers or owners. For example, Zurich does not allow buildings to be constructed if the city does not believe the building plans will lead to compliance with energy codes.

Another option for cities is to implement robust measurement and verification systems to track compliance with codes. Benchmarking ordinances in US cities such as Austin and Chicago can serve as data collection systems to track energy usage and progress on effective code implementation. The data collected measures, at a macro level, whether actual energy use levels converge with expected energy use based on code. While they typically don't link to code enforcement with specific buildings, the data can inform future actions on how to improve implementation.

4. Ease compliance challenges through knowledge building and incentives

Compliance is a challenge for all markets. While capacity to oversee enforcement is key, other actions can be taken by government or private entities to ease compliance. Knowledge building among designers, owners, and operators of buildings, as well as government officials and even tenants, on the benefits of and pathways to low-carbon buildings is a foundation upon which compliance must rest. Financing and funding to help with compliance can also ease the transition to new codes or to newer levels of performance in existing codes.

Knowledge building: Education on low-carbon buildings is foundational to improving compliance with energy codes. Education is especially powerful for the construction and architecture industry. Training and sharing best practices can be done on a governmental level or a private level. A key way to reduce the knowledge barrier is through codes that incorporate regionally specific design, as local construction firms will start with a strong understanding of the requirements. Education can improve the technical knowledge of architecture and construction firms, improving their ability to comply with energy codes. On a city level, Austin and New York City offer up-front technical assistance on code compliance to all developers and builders and Singapore maintains a website with easily accessible information on code compliance. Any effective program requires that government employees are up to date and able to engage other sectors and lead the work.

AN INTENTIONALLY CULTIVATED EXPERT COMMUNITY IS A BUILDING BLOCK FOR LARGER CHANGE ACROSS THE BUILDING SECTOR.

For the general public, as well as owners and tenants of buildings, information about energy efficiency can create demand for low-carbon buildings that comply with or even exceed code. Specifically, education on the long-term economic benefits of low-carbon buildings and feedback on their individual impact on sustainability can drive consumer demand for code-compliant buildings. This knowledge sharing could be done in any typical public awareness campaign or through demonstration projects by the local government. An increased understanding of low-carbon construction by owners may also allow them to serve as secondary checks for compliance on their own properties.

Incentives for new codes and guidelines: Incentives can smooth the transition when energy codes are new or newly updated. In markets that are implementing a preliminary or stricter code, the incentives can help overcome financial risks associated with higher construction costs. For example, the City of Accra aims to provide funding or incentives for buildings constructed with low-carbon techniques to help private organizations overcome concerns about high up-front capital. And the country of Nigeria will offer energy ratings to buildings complying with code in the two years before it becomes mandatory.

5. Foster leadership buildings and platforms in every market

Someone has to be first. Every market needs visible examples of low- and no-carbon buildings and a set of champions who can make them happen. Leadership platforms and buildings serve as a way to prove low-carbon buildings are possible and to build local capacity and commitment for scale. This work may also pave the way to low- or zero-carbon mandatory regulations.

Leadership platforms: Leadership platforms, or large-scale collaboration or commitments by multiple organizations to move toward low-carbon buildings, demonstrate the commitment and capacity of the government and other stakeholders. They also provide a role for both the architecture, engineering, and construction industry and the buyers and tenants of the majority of buildings to commit to and contribute to the transition to low-carbon buildings.

A number of private architecture leadership platforms already exist and set targets for low- to zero-carbon building development, including the China Accord in China and the AIA 2030 Commitment in the United States. The World Green Building Council's Net Zero Carbon Buildings Commitment is a new global effort focused on net-zero portfolio operating emissions by 2030 and 100 percent net-zero buildings by 2050; as of August 2018, 19 global cities had signed on.[110]

Cities can also foster thought leadership platforms for front-runner firms, designers, builders, and development professionals to engage with one another, share best practices, and accelerate change in various sectors. An intentionally cultivated expert community is a building block for larger change across the building sector. For example, the City of Chicago started Retrofit Chicago, a leadership challenge for buildings to commit to energy reductions, which allows participating operating engineers and property managers to share best practices. Similarly, a public–private partnership in Vancouver created the Vancouver Zero Emission Building Centre of Excellence, a platform to encourage the delivery of zero-emissions buildings by both industry and public stakeholders.

Leadership buildings: Leadership buildings serve as demonstration projects that showcase both the feasibility of building to low- or no-carbon standards and the benefits of doing so. On a local level, both private developers and the government can construct leadership buildings to demonstrate the benefits of low-carbon building in established, middle-income, and developing markets. Such demonstration projects are especially important for local governments in developing and middle-income markets where private investment may not have transitioned to low-carbon construction.

There are several examples of city government taking the lead in demonstration projects. The City of Accra, for example, focused on demonstration projects on two public buildings and is aiming to make city hall energy efficient. In Makassar, Indonesia, the city government has installed rooftop solar panels on municipally owned buildings and is engaging in conservation protocol by turning off electricity by 6 p.m. in applicable buildings.

6. Link codes to larger decarbonization efforts in energy supply, compact city development, and transportation

Energy-efficiency improvements, cultivated through code, can get a building 70 to 80 percent of the way to zero CO_2 emissions,[111] but the rest must come from changes beyond efficiency. The energy source used to power the building itself must be addressed. In addition, significant urban emissions come from transportation—a foundational topic for all cities. Energy codes have the potential to link low-carbon buildings to larger low-carbon city efforts by addressing more expansive topics, including renewable energy supply, compact city development, and sustainable mobility. These topics are often found in voluntary certifications, setting the stage for more comprehensive delivery.

Energy supply: True low- or no-carbon buildings must be tied to clean energy. A transition to renewable energies can reduce concerns about air quality from coal or biomass sources, while reducing greenhouse gas emissions. Energy codes globally will need to take energy supply into account and do so without endangering the underlying high-efficiency performance.

Energy markets also have a link to building codes. Markets are increasingly structured as multidirectional platforms wherein "negawatts"—or units of energy demand avoided as a result of efficiency efforts—can actually be represented and valued as a unit of energy "supply." Buildings can then supply renewable energy from on-site production, such as solar panels, as well as zero-carbon negawatts.

Location and site orientation: Urban planning and design decisions about the location and dimensions of individual buildings have strategic and citywide consequences for energy use and CO_2 emissions, specifically by influencing site emissions and transportation emissions.

Medium- to high-density urban form is a key building block for resource-efficient cities.[112] It becomes significant for the viability of other infrastructure solutions, such as district energy systems and transit, which generally require a certain population threshold for successful operation. For example, Warsaw relies on district heating to cover 80 percent of city residents and credits the system for reducing coal use and subsequently CO_2 emissions.

At the site level, orientation of a building is also important as it can influence natural lighting, ventilation, and the passive solar gain of buildings, as well as the performance of on-site solar generation. For example, the first LEED-certified building in Tanzania was designed with the changing location of the sun in mind, with features to help cool the space while optimizing daylight. In addition, site-level design specifications for surrounding green space assist in cooling adjacent buildings and building-level features such as green facades and roofs can have a role to play in cooling adjacent spaces and the overall microclimate surrounding a building.

Mobility: Green building standards, energy codes, and general city policies globally can take these larger spatial- and urban-planning considerations into account, specifically thinking about the contributions of individual buildings to support walkable and transit-friendly communities. For example, as part of its larger urban-development strategy, the City of Cape Town instituted a policy to limit construction to specific areas to intensify and diversify development within particular zones and avoid new sprawl. Cities can also act on a smaller scale on this issue when planning new transit systems or neighborhoods. For example, Guangzhou built a bus rapid transit corridor that connected bus stations directly to buildings.

Cities have developed tools to link new construction to low-carbon urban-development patterns. Approaches can complement codes while happening outside of them. The City of Chicago's Sustainable Development Policy is an example that lies outside of codes but that is required for all large projects. It has a point system that covers multiple elements of a sustainable building, including energy source, transportation, and even workforce development.[113]

7. Account for energy use throughout a building's life span

When the first building material is created or extracted, the energy impact of a building has begun. As more buildings are built and as the existing stock is renovated, the scale of materials used and the energy impact of the overall construction process expands rapidly. In addition, in some urban areas, the life span of many buildings is measured in years, not centuries. Longevity needs to be addressed, as demolition adds emissions. Cities will need to account for the full impact of these scope 3 emissions to address locally produced carbon.

Construction materials: The establishment of standards or labels for construction materials is a critical way to address embodied carbon. Labeling for construction materials typically falls on the national government, which can set regulations to encourage the development and use of low-energy intensive building materials.

The labeling of construction materials discloses the environmental impact of a product. The use of Environmental Product Declarations by private industry can aid in the disclosure process. In the European Union, the Construction Products Regulation provides a common technical language to assess construction products' performance. The regulation ensures reliable information is available for comparison of products.

To advance efforts on embodied carbon, local governments—both city and provincial or state level—can include language on embodied energy in their building energy codes or policies. For example, the City of Zurich addresses its efforts for building energy reductions in two ways: the energy consumption during operation and the embodied energy consumption from construction, use of materials, and demolition.

A number of voluntary standards include embodied energy in its requirements to try to account for these emissions. Minergie in Zurich requires that embodied nonrenewable energy may not exceed 50 kWh per area. Similarly, the German Sustainable Building Council announced a framework for carbon-neutral buildings, which includes reducing embodied CO_2 emissions in construction materials as a priority. LEED also offers credit for addressing embodied energy at the construction and demolition phases. Cities, states, and national governments can include similar requirements in codes or related policies.

Renovation: Renovations offer a critical way to address lifetime carbon. Considering the energy performance of the capital improvement can help avoid locking in high carbon usage for years to come. Current evidence suggests that renovation rates will need to increase from less than 1 percent to 2 and 3 percent in developing- and established-market countries, respectively.

To support these efforts, city, state, or national governments can look to policies that require renovations at certain phases of the buildings' lifetime or during the renovation cycle. Energy-efficiency improvements during the capital improvement process cost about 75 percent less. For example, New York City requires any building larger than 50,000 gross square feet to undergo an energy audit and make relevant improvements every ten years. This is especially important for established markets with significant existing building stock.

8. Drive energy impact outside of codes through incentives, appliances, and bulk procurement

While codes are critical, many markets do not have stringent codes or have no codes at all. And even when codes are in place and enforced, they typically do not cover all energy use over a building's life span. A more comprehensive approach is needed. Cities can focus on a number of actions to address energy use in buildings outside of building energy codes—supporting appliance standards, using bulk procurement to lower prices for energy-efficient equipment, and providing incentives for developers and builders to go beyond the standards of existing codes.

Appliance standards: A contributing factor to energy consumption within buildings is the use and energy performance of appliances. The current gains from improvements in appliance efficiency do not compensate for the increases in overall demand, suggesting the need to promote further efficiency improvements. Efforts to advance appliance energy efficiency can aid in reducing energy load in conjunction with building codes. These efforts are increasingly significant when codes are not yet implemented.

Authority for appliance standards often lies with national governments. To address the increase in energy demand from appliances, national governments can implement energy-efficiency requirements for use of the best available technology and cities can engage in the process by advocating for more stringent standards. Cities can also support programs that educate and encourage citizens to replace inefficient appliances and dirty cooking fuels with more efficient appliances and methods.

The private sector can engage by installing and creating market demand for energy-efficient appliances. Private organizations can also work to encourage national governments to transition to efficient appliances. For example, the UN Environment initiative en.lighten promotes LEDs and a ban for incandescent light bulbs, K-CEP helps nations transition to more efficient cooling equipment, and the United for Efficiency (U4E) UN Environment and Global Environment Facility partnership works to deploy highly efficient appliances.

Bulk procurement: To engage in the transition to energy-efficient appliances and technologies, city governments or private agencies can use bulk procurement to help local consumers afford energy-efficient or renewable technologies and to retrofit buildings, greatly expanding the scale of impact.

For example, in India, bulk procurement of LED lights, fans, and air conditioners saved money for all consumers. A government of India company, Energy Efficiency Services Limited, reduced the manufacturers' price for LED light bulbs through large-volume purchases. The company then sold the bulbs to consumers in India, which increased demand for LED bulbs by 50 times in three years.[114] These efforts were expanded to fans and air conditioners. For air conditioners, the company included minimum energy-efficiency requirements in the original request for purchase.

On a building scale, Energiesprong, operating in developed countries, aggregates mass demand for zero-energy high-quality retrofits and newly built houses in a market. This effort creates the ability to complete a large number of projects within a short period of time for a lower overall cost.[115]

Incentives: To further encourage energy-efficiency improvements, governments can provide funding and incentives for actions that go beyond code compliance. The World Economic Forum and IEA state that the building sector will require close to $4 trillion between now and 2030 to meet climate goals. Compared with current funding levels, this means that the sector needs an additional $3 billion in annual investments.[116]

To contribute to this need for financing, city, state, and national governments can look to supporting and expanding financing for commercial and residential efficiency initiatives. These programs can have a measurable impact. For example, in C40 cities, financing programs for rebates in commercial and residential buildings resulted in 70 percent of the change in C40 cities.[117] Incentives from cities or national governments may include subsidized loans or interest rates for green buildings, awards or public recognition, tax benefits, or partial grants for energy-efficient measures on new buildings.[118] A specific example is a fee structure for permitting that charges lower fees for buildings that exceed existing standards. Following this structure, the state government of Andhra Pradesh in India offers a 20 percent reduction on permit fees for buildings that receive a rating from the Indian Green Building Council.[119]

9. Support research and innovation

From breakthroughs in clean-energy generation to faster deployment in the commercial market to better analysis and support for local policy and action, research and innovation must accelerate the transition to low-carbon buildings, systems, and cities.

Nationally funded research typically supports the quest for major breakthrough technologies. Renewable energy, energy-storage technologies, low-energy-intensive construction materials, techniques to address the urban heat island effect, and new innovative low-carbon equipment that can support cities or be incorporated into urban settings are all needed. With growing density and stretched energy-supply systems, as well as with the potential to link transportation to buildings, urban infrastructure can use technological breakthroughs to solve carbon and health challenges.

The transition from lab to market demands strong commercialization efforts with a global focus on the needs of billions of people. Private-sector partnerships and rapid feedback from urban residents of all income levels can shape the next waves of technology deployments and policies. For example, in Los Angeles, the local government is undergoing a stakeholder engagement process with local experts to identify innovative changes to building policies and processes. The government hopes to "futurize" policies and processes that influence how the city designs and builds buildings.[120]

Scale often comes from good policy. From building energy codes to broader low-carbon policies, cities need data and tools on effective actions that deliver meaningful results. Innovation only matters when it solves real problems for real people.

CONCLUSION

In the years ahead, skylines everywhere will change. The expected doubling of global building square footage simply cannot be hidden. The question cities have to answer is whether that change will ensure a thriving low-carbon future or hasten a looming climate and energy crisis.

Conversations with a small group of cities from multiple continents show cities are fighting for the residents of today and tomorrow. From developing economies like Visakhapatnam to established old-world cities like Zurich and everywhere in between, cities are creating portfolios of actions to shape a low-carbon future in economies that can support residents.

At the heart of these strategies lie buildings. Buildings today already drive global CO_2 emissions—and construction rates are increasing their importance. Addressing carbon from buildings starts with ensuring they are built to be efficient and to use clean energy sources to operate, roles that building energy codes increasingly play.

Efficiency is a “must have” for low- and zero-carbon buildings and cities, but on its own it is insufficient. It must be married to reductions in the carbon in energy supply, the emissions from transportation, and the impact of building construction. While traditional building energy codes typically do not extend to broader issues, voluntary sustainable building certifications often make the connection and city actions can help promote and expand the impact.

As cities face broad global challenges and opportunities, they do so from very different starting points. The existence of codes, local knowledge and expertise, financial resources, local weather patterns, population growth, and government capacity, among others, all vary. Consistent principles on aggressive, comprehensive, and enforced codes linked to broader systems, however, can support every city on the path to a thriving low-carbon future.

That path will require broad partnerships locally and internationally, ever-evolving technologies and practices, thoughtful policy, relentless optimism, and dogged persistence. It requires the best of cities.

APPENDIX

Energy efforts for buildings can be shaped by a variety of institutional actors, each of which has the potential to drive the transition to low- to zero-carbon buildings and thriving, low-carbon cities. The principles developed in this report were assessed looking at public, private, and nongovernmental or civil society actors.

The three levels of public sector actor identified include governments at the city, state/provincial, and national levels. City-level governments have the most direct connection to local efforts and consumers, and often have authority over enforcement of policies or codes. State-level actors influence low-carbon buildings and communities through setting state-wide policies, which directly affect codes, incentives, or funding within cities. And national government actors often set the general frameworks for climate action or building codes, in part by directly influencing the authority of subnational governments in this area and by funding energy and transportation projects.

Nongovernmental and civil society actors can cut across all three levels of government to play a knowledge building and consolidation role, convening and facilitating stakeholder engagement across sectors and markets, and helping develop normative guidance for policy development and implementation.

Private sectors around building energy codes and efficiency can be thought of as falling into two separate groups: 1) the architecture, engineering, and construction industry and 2) the owners, tenants, and renters of buildings who have real estate footprints as a function of their business operations. The architecture, engineering, and construction industry has significant influence on building efficiency through its direct role in designing, developing, and constructing buildings. Owners, tenants, and renters can shape low-carbon building efforts through demand-side levers for efficiency and low- to zero-carbon building practices. The matrix in Table 1, “Principles and key institutional actors,” highlights possible actions and roles that each actor type is well positioned to carry out with respect the nine principles outlined in this report.

Table 1: Principles and institutional actors

Local government	State/provincial government	National government	Private sector: Architecture, engineering and construction industry	Private sector: Commercial and corporate sector at large	NGO/ Civil society
1. Treat building energy codes as part of a larger transformation					
Frame building stock as key lever for thriving city vision across energy use, mobility, and urban-development patterns	Align regulations and programs to support cities' efforts to transform their built environments	Align regulations and programs to support cities' efforts to transform their built environments	Support broader efforts	Support broader efforts	Pursue and promote research regarding the role of built environment in anchoring thriving, low-carbon cities
2. Develop ambitious and appropriate building energy codes in all markets					
Convene diverse stakeholders to inform code development and implementation Ensure code speaks to concerns of multiple constituents Where authorized, change code	Take legislative and regulatory action for code adoption Grant shared authority for codes to local government Support with technical assistance	Take legislative and regulatory action for code adoption Grant shared authority for codes to local government Support with technical assistance	Iterate and experiment to shape future code and lessen compliance burden	Buy or rent in buildings that exceed code requirements to push improvements in code	Serve as an intermediary and facilitator for stakeholder engagement across levels of government and sectors Advocate for code adoption and code sensitivity to regional context
3. Implement robust enforcement and tracking mechanisms					
Implement robust inspection requirements Educate and train inspectors on energy code requirements Set penalties for noncompliance	Support city capacity to inspect buildings	Support city capacity to inspect buildings	Serve as third-party inspectors	Adopt voluntary compliance and tracking mechanisms Support and comply with mandated enforcement and tracking mechanisms	Aggregate and share best practices and learnings across levels of government for successful compliance enforcement strategies

Local government	State/provincial government	National government	Private sector: Architecture, engineering and construction industry	Private sector: Commercial and corporate sector at large	NGO/ Civil society
4. Ease compliance challenges through knowledge building and incentives					
Provide information and education to private-sector actors Provide incentives to overcome initial financial risks	Aggregate experiences to provide information and education to private- sector actors Align policies, codes, and standards across jurisdictions Support local actions	Aggregate experiences to provide information and education to private-sector actors Align policies, codes, and standards across jurisdictions Support local actions	Share best practices and learnings	Share best practices and learnings	Aggregate experiences to provide information and education to private-sector actors Advocate for the alignment of policies, codes, and standards across jurisdictions
5. Foster leadership buildings and platforms in every market					
Foster demonstration projects in collaboration with private sector Lead by example with own buildings	Provide visibility and seed funding for demonstration projects and platform efforts Lead by example with own buildings	Provide visibility and seed funding for demonstration projects and platform efforts Lead by example with own buildings	Join commitments for low-carbon construction	Provide proof of concept for ambitious projects that demonstrate code feasibility	Serve as an intermediary and facilitator for productive leadership engagement across levels of government and sectors
6. Link codes to larger decarbonization efforts in energy supply, compact city development, and transportation					
Develop and strengthen transit Mandate and/or incent on-site installation or charging infrastructure Create energy-mix portfolio target for off-site fuel sources Develop land use codes to ensure site- and building-specific compatibility with compact city plan	Support development of transit Mandate and/ or incent on-site installation or electric-vehicle charging Shape regional market for renewable supply	Support development of transit Incent on-site installation or electric-vehicle charging Shape national market for renewable supply Conduct research and development for breakthroughs	Design and build for optimal on-site generation performance Design and build for walkability and transit connectivity	Invest in off-site fuel switching to renewables Make real estate investments in walkable and transit connected locations Invest in on-site installment and vehicle charging	Pursue and promote research regarding the role of building codes linking to larger decarbonization efforts Advocate for codes and standards being strengthened to extend to larger efforts

	Local government	State/provincial government	National government	Private sector: Architecture, engineering and construction industry	Private sector: Commercial and corporate sector at large	NGO/ Civil society
7. Account for energy use throughout a building's life span						
	Introduce policy and regulation for sustainable sourcing, construction, operation, and demolition Introduce policy requiring renovations in appropriate phases of a building's lifetime	Introduce policy and regulation for sustainable sourcing, construction, operation, and demolition Introduce or support policy requiring renovations in appropriate phases of a building's lifetime	Introduce policy and regulation for sustainable construction, operation, and demolition Establish label standards for construction materials Introduce or support policy requiring renovations in appropriate phases of a building's lifetime	Procure resource-efficient building materials Pursue efficiency upgrades at time of renovation or construction Engage in sustainable demolition and material recycling	Prioritize sustainable operation of buildings Schedule investments in efficiency upgrades over a building's lifetime	Aggregate experiences to provide information and education to private-sector and government actors Develop and model impact of additional environmental product declarations
8. Drive energy impact outside of codes through incentives, appliances, and bulk procurement						
	Use bulk purchasing to shape market for sustainable supply Convert large city-owned demand centers to sustainable supply Provide incentives for going beyond code	Use bulk purchasing to shape market for sustainable supply Convert large state-owned demand centers to sustainable supply Provide incentives for going beyond code	Implement stringent appliance standards Use bulk purchasing to shape market for sustainable supply Convert large demand centers to sustainable supply	Respond to bulk purchasing opportunities with sustainable supply option to meet demand	Use bulk purchasing to shape market for sustainable supply Invest in energy-efficient appliances	Aggregate experiences to provide information and education to private-sector and government actors Organize and support bulk purchasing opportunities
9. Support research and innovation						
	Use simulations to understand code and policy performance	Guide strategic research and development investments to answer regionally specific concerns	Fund research on major technologies	Work with researchers Share failure cases and identify pain points Conduct own research	Work with researchers Share failure cases and identify pain points	Shape research agenda Serve as an intermediary and facilitator for productive stakeholder engagement across levels of government and sectors

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