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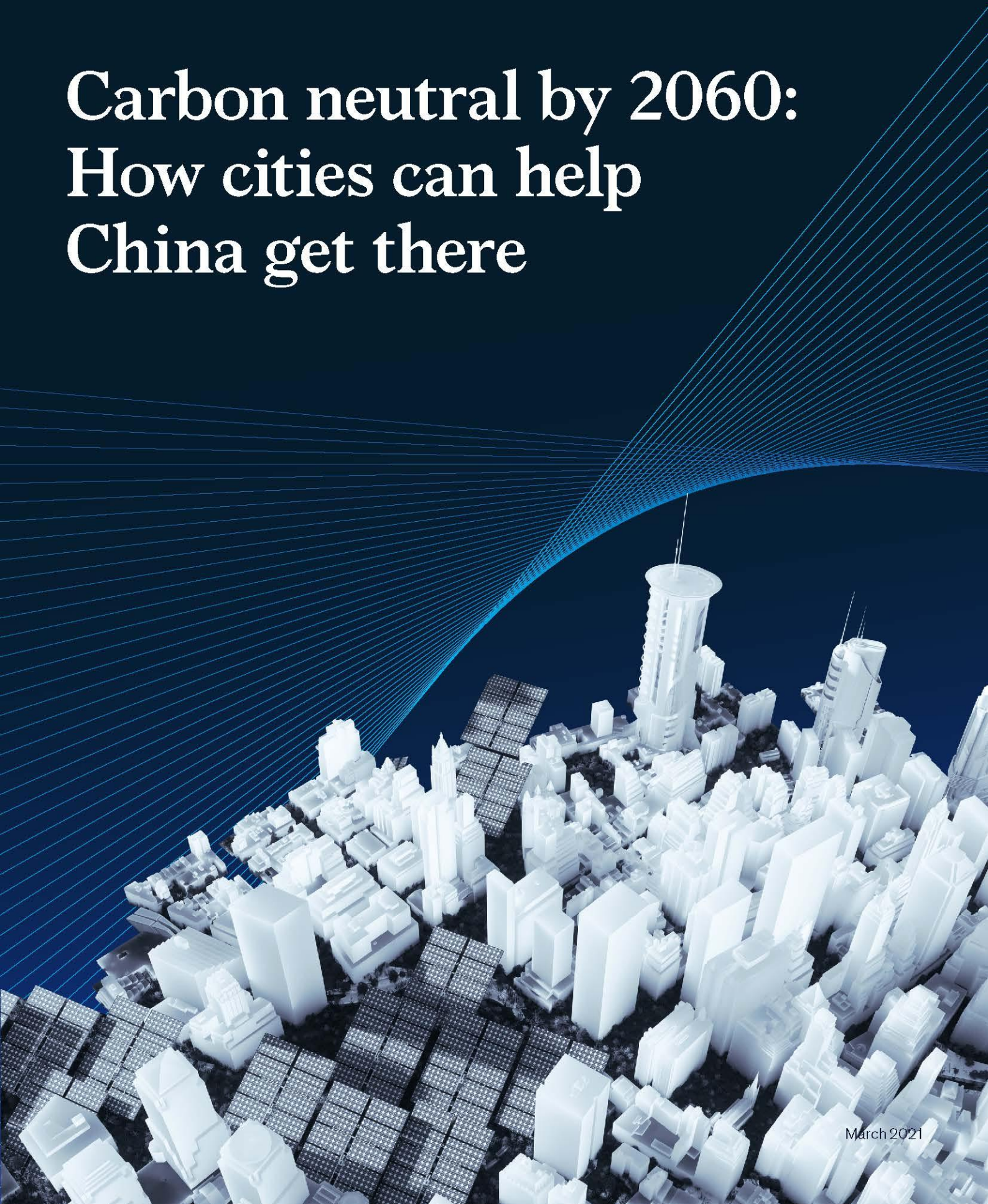
# Carbon neutral by 2060: How cities can help China get there



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## Introduction

Traumatic as COVID-19 has been, destroying lives and livelihoods around the world, an even larger risk could be looming: climate change. In Paris in 2015, almost every country on the planet agreed to take action to limit the rise in global temperatures to no more than 2 degrees Celsius (and preferably 1.5) above pre-industrial levels. But the pledges made in Paris would only account for a third of required emissions. More needs to be done—and cities have a major role to play.

China, which accounts for 28 percent of global emissions, has set a goal for carbon dioxide (CO2) emissions to peak before 2030 and to be carbon neutral by 2060. Meeting that target will be difficult, but the stakes are high. Average temperatures in China have increased as much as 1.5°C since 1909, [i] and climate change could mean a warmer and wetter country. Sea levels off eastern China rose 93 millimeters between 1980 and 2012, while glaciers have shrunk 10 percent since the 1970s.

That is the recent past. In the near future, if China's emissions continue to rise at the current rate, the threats of extreme heat and lethal heat waves could affect 10 to 45 million people by 2030. The kind of heavy precipitation that was a once-in-50-years event in 1980 is expected to be two to three times more likely in 2030 and three to six times more likely in 2050. The average share of outdoor working hours lost each year to extreme heat and humidity would increase from 4 percent to as much as 6.5 percent in 2030 and 9 percent in 2050; the latter would be equivalent to $1 trillion to $1.5 trillion in GDP.

Coal supplied around 58 percent of China's total energy consumption in 2019, a figure that is gradually declining. In addition, the country has been diversifying its energy supplies and shifting towards a cleaner and less energy-intensive economy. But China's overall coal consumption continues to rise slightly, driven by demand growth in electricity, residential heating, as well as industries such as steel and cement.[ii] And lower-emissions energy sources still account for less than a quarter of China's primary energy usage: hydroelectric (8 percent), natural gas (8 percent), nuclear power (2 percent), and non-hydro renewables like wind and solar (5 percent).

China accounts for almost a third of global investment in renewable power and fuels; in 2018, it was home to more than 95 percent of the world's electric bus fleet and nearly half of all electric vehicle (EV) passenger cars.[iii] Energy efficiency and the greater use of renewables has also helped reduce air pollution. According to the International Energy Agency (IEA), China is set to account for 40 percent of global renewable capacity expansion to 2024. In short, then, China is gradually greening its energy supply, through the greater use of renewables, natural gas, and electricity. But its growing economy, and continued reliance on coal, means that China's road to carbon neutrality will be long and difficult.

As the wellspring of both economic growth and greenhouse gas (GHG) emissions—15 cities account for a third of the country's GDP[iv]-- Chinese cities have a major role to play in decarbonization. Cities are also equipped to take action. They are home to key decision makers, large investment funds and investors, leading universities and think tanks and a growing number of high-income individuals interested in promoting sustainability. Four areas are critical: decarbonizing their electricity grid; optimizing energy efficiency; encouraging next-generation mobility; and strengthening consumer demand management. And they can also play a role beyond their own boundaries. By developing and scaling up climate solutions; mobilizing investment; and supporting international collaboration, China's cities can help further regional and even global decarbonization.

To demonstrate how that could happen, we first offer a global perspective on how cities can decarbonize. Section 2 looks specifically at how the city of Beijing can become a leader in

decarbonization and related technologies. Section 3 considers what China's cities can do to foster regional and global decarbonization. Finally, Section 4 discusses the respective roles of the public and private sectors.

## Section 1: A global perspective on urban decarbonization

Since the 1880s, the Earth's average temperature has risen by about 1.1 degrees Celsius. A warmer

Earth could mean that acute physical hazards such as heat waves and floods could grow in frequency and severity, and chronic hazards, such as drought and rising sea levels, could intensify.

Under the Paris Agreement, which China signed in 2016, meeting the 1.5°C goal requires staying within a global "carbon budget"(the cumulative amount of carbon dioxide emissions permitted to keep within a certain temperature threshold), of 570 gigatons of CO2. Under current projections, even if all the nations who signed meet their commitments, the 2-degree carbon budget will be about 80 percent depleted by 2030,[v] and the 1.5-degree budget almost gone.[vi]

While cities only account for about 2 percent of the global landmass, they consume two-thirds of the world's energy, house 55 percent of the world's population, contribute 70 percent of global CO2 emissions,[vii] and generate about 80 percent of global GDP[viii] —85 percent in China. As urbanization advances, all of these figures could rise. With 65 million people a year moving to cities, they could be home to almost 70 percent[ix] of the world's population by 2050. Cities therefore have enormous influence on the trajectory of GHG emissions.

Speed, then, is of the essence: the choices and investments cities make today, on everything from energy and building standards to land use and public transit, will affect emissions for decades to come. To meet their emissions targets, cities need to prioritize their actions and then ensure that the conditions are in place to execute them. There are five priorities.[x]

### *1.1 Decarbonizing the electricity grid*

To limit global warming, the world will have to significantly reduce the consumption of fossil fuels and expand low- and no-emissions power generation, such as hydro, nuclear, solar, and wind.[xi] Cities have opportunities on two fronts: investing in the expansion of centralized renewables and enabling the smart expansion of distributed renewables. With focused acceleration and close collaboration with utilities and regulators, cities could achieve a renewable grid mix of 50 to 70 percent by 2030, accounting for 35 to 45 percent of the total emission reductions required.

There are examples of how this could work. Copenhagen, for example, launched a cooperative in 2000 through its own utility to invest in a 40-megawatt wind farm two kilometers off its coast. Denmark's national energy producer, Orsted, also has an ownership stake and the electricity produced is sold all over the country. Denmark's ultimate goal: to supply half of its electricity with offshore wind.

Even cities with less-favorable conditions for renewables have found innovative ways to decarbonize their electricity supply. Melbourne gets its energy from a utility that uses coal for 90 percent of its power generation. Its city center is dominated by high rises, leaving little space for on-site renewables.[xii] Working within existing national policy, the city worked with government, cultural, and educational institutions since 2016 to develop a renewable-energy procurement system to buy 110 gigawatt (GW) hours of new renewable electricity per year over ten years.[xiii] A second phase added more. Together, the new sources have reduced the city's emissions by five percent.

### *1.2 Optimizing energy efficiency in buildings*

With millions of space heating systems, air conditioners, hot water, lights, appliances, and equipment, buildings are the biggest consumers of energy in most cities – and the biggest emitters of CO2. Heating and cooling account for 35 to 60 percent of energy use in buildings and generate, on average, nearly 40 percent of urban emissions. Cities can significantly

reduce emissions by addressing not only the efficiency of appliances and equipment but also the efficiency of commercial and residential buildings themselves. Our analysis indicates that many cities can meet up to 55 percent of their emissions abatement targets by improving how buildings consume energy; that does not include additional opportunities in appliances.

There are five major opportunities: raising energy efficiency standards for new buildings; retrofitting building envelopes (cooler roofs, improved wall insulation, high-efficiency windows, and better air seals on door frames); upgrading heating, ventilation, and air conditioning (HVAC) systems with lower-carbon technologies; using more LED lighting; and expanding the use of building automation and controls. Investments in these areas can often be recouped in five to 15 years, while building a foundation for long-term resilience, clean air, and livability.

The city of Brussels has demonstrated that building to high standards in heating, cooling, energy demand, airtightness and ventilation, can cost almost exactly as much as conventional, lower-efficiency construction. Operating costs in what are known as "passive buildings"— ultra-low energy structures that require little or no energy for space heating and cooling—are, however, much lower. Tokyo's Sky Tree Town, a complex consisting of a high-rise residential building as well as commercial facilities and offices, uses a combination of heat pumps and water tanks in its multi-building HVAC. This "district system" has reduced energy use by 44 percent and emissions by 50 percent compared with individual systems.[xiv]

For existing stock, renovating the building envelope can reduce heating and cooling demand by 40 percent and allow the installation of smaller HVAC systems or the use of natural ventilation to limit the need for heating or cooling altogether. Cities such as San Francisco and Toronto have created programs to enable lower-income communities to retrofit their homes, improving HVAC operations while reducing health hazards such as indoor condensation and mold in the process.[xv]

### *1.3 Encouraging next-generation mobility*

As cities grow, so does the movement of goods and people. Options for better, cleaner mobility include accelerating transit-oriented development; encouraging mass transit, walking, and cycling; and enabling next-generation vehicles, including freight transport. On the latter, there are four powerful trends to work with: electrification, shared mobility, autonomous vehicles and wireless connectivity.[xvi] Combined, these mobility opportunities could account for a significant share—20 to 45 percent—of the urban emissions reductions needed by 2030.

Cities can provide incentives and regulations to speed EV adoption, such as subsidies, designated driving lanes and parking spots, and support for the construction of charging stations. More than 220 European cities have implemented or plan to implement zero- or low-emission zones.[xvii]

For example, the northern California city of San José—home to one out of five EVs in the United States, launched a $14 million project in 2020 to double the availability of charging infrastructure and to increase access to zero-emission vehicles.[xviii]

These are the most promising actions. To get there, cities need to engage with people and invest in technology. The swift and sure development of these three "enablers" is essential to reaching carbon neutrality.

### *1.4 Strengthening consumer demand management*

Encouraging customers and industries to participate in decarbonization initiatives—for example, by promoting lower-carbon options and building a circular economy—can help cities meet their targets.

Adopting a green lifestyle does not necessarily mean consuming less, but doing so in a way that protects the environment and improves the quality of life. For example, shifting to a more plant-based diet, or using more soy milk, can bring health benefits while lowering carbon emissions for agriculture.[xix] Or take the sharing economy, whether of cars, tools, or other items; this can cut both consumer costs and product waste. Many workers have changed their travel and commuting patterns due to the pandemic; this has not only reduced emissions from aviation and, in some places, cars, but working from home has also improved productivity for many companies. The government of Wales, for one, is devising policies to encourage remote working, for example by supporting remote working hubs. [xx]

By offering learning opportunities in schools, community centers, and other agencies; hosting decarbonization or future of mobility exhibitions; and establishing volunteer programs, cities can help their residents become more sustainability-conscious—and perhaps increase demand for low-carbon products and solutions.

*Implementing "circular economy" principles.* Energy efficiency and switching to renewables would only address 55 percent of GHG emissions. The rest comes from how food and products are made and used. That is the role of the "circular economy"—in which products and materials are kept in use, in a virtuous cycle of design, use, and reuse. Instead of tossing materials into landfills or incinerating them, a system of resource management, nutrient flows, and reverse logistics makes the return, sorting, and reuse of products possible. Think regeneration, not reuse.

As an instrument to decouple economic growth from resource use and environmental impact, adopting circular economy principles could have major economic, social and environmental benefits, saving materials costs and significantly cutting GHG emissions.[xxi]

City governments have an important role to play in building thriving, livable, resilient cities that are regenerative by design. One way for cities to embed circular economy principles is to foster closer proximity between where people live, work, and play. The air gets cleaner as vehicles switch to zero-emission engines and congestion reduces as shared transit increases. More people walk and cycle to work, boosting health and interactions with local businesses and communities. Land that was previously dedicated to roads and car parks could become green spaces or new homes and businesses.

By working with various stakeholders to raise awareness of circular economy practices, embedding them into planning, and the use of economic incentives and regulation, cities can be part of the transition from a take-make-waster linear economy to a cleaner and more production circular economy. The city of Brussels has begun working towards this vision, allocating €13 million a year to the Brussels Regional Programme for a Circular Economy.

Since 2016, more than 200 companies and 1,400 individuals have been educated and supported in the implementation of circular economy approaches.

***1.5 Spurring investment in low-carbon technologies.***

If countries genuinely commit to cutting their emissions in line with the Paris agreement, demand could grow for a wide range of low-carbon technologies, including wind turbines, solar photovoltaics (PV), energy storage, metal recycling, EVs, hydrogen fuel cells, and carbon capture utilization and storage (CCUS). With their political, financial, and human resources, cities can be ideal incubators and testing grounds. Through collaboration with regional governments, industry leaders, academic institutions and think tanks, cities can offer grants, funding, space or other resources for innovation. Finally, to put ideas into actions, cities need to set specific targets for new technology implementations. Tokyo, for example, has stated a goal of 1 million residential fuel cells and 150 hydrogen stations by 2030 as part of its effort to ensure that hydrogen is a key part of its Zero-Emission Tokyo Strategy. [xxii]

## Section 2: Case study: How Beijing can become a decarbonization role model

Many of China's most important cities are characterized by capable local government, well-established decarbonization plans, supportive private and state-owned companies, and world-class universities and research institutions. Decarbonization, then, is well within their capabilities. In this section we consider the example of Beijing, examining what it is doing; where it has succeeded; and what comes next.

The city of Beijing emitted 150 million tons of CO2 in 2018, 70 percent from buildings and transportation, a share that is expected to increase as Beijing continues its transition to a service-driven economy.[xxiii] The contribution of industry to the city's GDP fell from 20 percent in 2016 to 16 percent in 2019,[xxiv] as heavy industries like Beijing Shougang, a steel manufacturer, moved to other regions. The remaining heavy industries, such as Yanshan Petrochemical, are likely to do so in the future. Even so, overall emissions are still rising.

The city has taken several effective actions to reduce its carbon intensity by half since 2010, and it is now the lowest in China.

- Phasing out coal: Coal is no longer the main residential heating source, replaced by natural gas and electricity-based heating devices.
- Energy efficiency: Beijing has set clear goals for energy consumption and intensity, and cut the latter by 13 percent from 2016 to 2020.
- Transportation management: The expansion of public transportation and support for EVs, including charging infrastructure, has helped decrease emissions from transportation. In the last five years, the length of the Beijing subway system has risen by a third.

In a sense, Beijing has already picked the low-hanging fruit. What comes next, such as the deployment of autonomous vehicles (AVs), hydrogen, and carbon capture, utilization and storage (CCUS), will likely be more expensive and complicated. Moreover, the service and household sectors consume more than 80 percent of the city's energy. Their emissions are more difficult to track than those of large industrial companies, and traditional top-down approaches are less effective. This, however, is true for many cities, and can also be seen as an opportunity for leadership.

### 2.1. Mobilization: How Beijing can help develop grassroots responses to climate change

Cutting emissions requires changing how companies and individuals conduct their daily lives, from how they build their homes, to how they travel, to how they stay warm or cool. The following four actions have high potential.

#### *2.1.1 Decarbonizing the electricity grid.*

This needs to be the first step, because decarbonizing the grid is also a necessary condition to decarbonize other parts of the economy, including building and transportation. The city of Beijing purchases about 70 percent of its electricity from the surrounding regions, including Hebei, Inner-Mongolia, and Shanxi.[xxv] These provinces historically generated power from coal, but have recently been investing heavily in renewable energy. Zhangjiakou, in Hebei province, for example, has built several wind farms with capacity of more than 10 million gigawatt (GW). One approach, then, is for Beijing to work with these provinces to build even more renewable capacity. Here are two options.

*Expand distributed solar power generation.* Due to Beijing's population and building density, the potential to expand distributed solar power within the city is limited. It could, however, expand solar power distribution to suburbs such as Shunyi and Pinggu, which have more land available. These resources could be connected to the central grid to allow the sale of surplus electricity.

*Increase demand-side grid flexibility.* Because wind and solar are intermittent, the more they are used, the more important it is that there is real-time, demand-side flexibility to fill the gaps. One way to do so is to adopt time-of-use (TOU) electricity pricing, with higher prices for peak-hour usage. This helps to ensure that demand matches supply. Beginning in 2015, Beijing started such efforts, but because the price differential was minimal, consumers have been slow to change their behavior. To amplify the effect of TOU pricing, demand-side electricity storage should be encouraged. For example, commercial buildings could install batteries to store electricity at non-peak hours for peak-hour use, or EV owners could sell electricity to the grid during peak hours.

### *2.1.2 Optimizing energy efficiency in buildings.*

Buildings are major emitters in Beijing, with municipal and commercial units accounting for about half of all building energy consumption. Many of them have the resources to upgrade to high-efficiency equipment and appliances. Most building-efficient investment can be recovered in five to 15 years. Here are four promising strategies.

*Install high-efficiency equipment and appliances.* Heating and cooling are the largest sources of building emissions—and many Beijing buildings have distinctly old-fashioned HVAC systems. Installing low-carbon technologies, such as electric heat pumps, high-efficiency air conditioning, and electric- or solar-based heating, can help decrease emissions. For lighting, Beijing needs to continue its ongoing shift to more efficient LEDs. [xxvi]

A more ambitious plan of action is to install more automation and upgrade management. Adaptive thermostats connected to the Internet allow users to automatically adjust room temperatures using motion sensors and can even adjust bulb brightness to the level of sunlight.[xxvii] Toronto, Sydney, and a number of cities in the United Kingdom have started partnerships to provide real estate companies with the information, tools, and technical and market support to accelerate improvements in building efficiency.[xxviii]

*Promote low-energy consumption design.* Improved building design can reduce the need for heating[xxix]and cooling once structures are built; that is one of the principles behind a new energy-efficiency building code that will come into effect in Beijing later this year. Beijing can eventually upgrade the code to incorporate ambitious net-zero standards, as the European Union (EU) is doing. Beginning in 2018, all new public buildings are mandated to be nearly zero-energy, and from 2020 onwards, all new buildings will have the same mandate.[xxx]

Beijing can designate zero-carbon neighborhoods or districts to test solutions, and to create opportunities for public-private collaboration. It can also encourage innovation in the low-carbon building value chain, such as new materials. In New York City, the Municipal Entrepreneurial Testing System allows businesses to test new green building technologies in municipal buildings before releasing to the market.[xxxi]

*Retrofit aging buildings.* Renovating aging buildings, focusing mainly on their envelopes, can reduce heating and cooling demand by as much as 40 percent, cutting both utility costs and emissions, while raising living standards. Four out of 10 apartments in Beijing were built before 1990; most could use such upgrades.

There have been efforts to retrofit aging buildings. In 2020, the Beijing municipal government paid to upgrade 80 aging apartment complexes as part of a broader renovation program.[xxxii] To scale up, Beijing could encourage private capital participation by exploring new business models. For example, the city government could consider bundling the right to develop commercial property with a residential retrofit project. Other options to encourage businesses and residents to act include subsidized loans, streamlined permitting processes, and starting a government-led bulk purchase program to lower capital costs. In 2016, Qingdao set up a retrofit incentive program to renovate housing stock. City leaders estimated that more than 50 million square meters of old residential buildings required efficiency upgrades. Almost half of the required retrofits have been completed, lowering expected emissions by an estimated 298,000 tons of CO2.[xxxiii]

*Implement smart measurement of building energy consumption.* When people have control over their usage, and understand the costs, they are more likely to change their behavior. Heating accounts for about 40 percent of energy consumption for residential buildings in Beijing. In most cases heating is charged per square meter, so residents tend to keep their heaters on all the time. Converting to heat metering is likely to make residents reserve energy. Kazakhstan, for example, launched a meter installation program as part of its green strategy. As of 2020, 60 percent of residential buildings are covered, with the goal of 100 percent by 2025[xxxiv].

### *2.1.3 Encouraging next-generation mobility.*

Passenger transportation contributes 10 to 15 percent of Beijing's GHG emissions[xxxv], with the majority coming from passenger cars. Beijingers like their cars; ownership has risen from 5.6 million in 2015 to 6.6 million in 2020. [xxxvi] The city has been working to encourage EVs. In 2015, it began efforts to electrify the taxi and bus fleets; it also offers favorable terms to EV car owners, such as additional purchase quotas. As a result, in 2020, EVs accounted for more than 60 percent of car sales in Beijing.[xxxvii] Nevertheless, gasoline-powered cars still account for around 95 percent of the wheels on Beijing's roads, and thus will remain a big emitter for at least the next decade. Here are three approaches to reduce transport-related emissions.

*Accelerate adoption of green vehicles***.** Beijing can set a clear timeline to ban the sales of petrol cars, as other cities are doing, including Los Angeles, Madrid, and Paris. With its extensive charging network—the biggest in China—and the fast uptake in EV sales, Beijing has an excellent foundation to phase out petrol cars. Automobile industries are preparing. BAIC, a large stated-own automobile company located in Beijing, stopped petrol car sales in the city from 2020.[xxxviii] If the government were to set an exact timeline, it would be easier for the entire car infrastructure to adjust and to ensure that there are enough charging stations. For example, the oil major, bp, and Didi, a car-sharing service, formed a new company in 2019 to build charging stations around China.[xxxix]

Beijing can also seize the opportunity to hasten the development of the hydrogen car industry. China plans to roll out one million hydrogen cars by 2030,[xl] up from 7,000 in late 2020.[xli] Within China, Guangdong has moved fastest, with the most hydrogen fueling stations; Guangzhou has also invited South Korea's Hyundai, an early mover in hydrogen cars, to build a hydrogen fuel-cell factory. [xlii] In building a hydrogen industrial park, Beijing would demonstrate its ambition to become a leading city in the Hydrogen Car industry. [xliii]

*Invest in transit-oriented development.* Better urban planning and development can reduce emissions by shrinking commutes. Beijing could launch transit development programs that connect sprawling areas with denser, mixed-use transportation hubs that include office buildings, stores, and education, leisure, and recreation opportunities. The ultimate idea is to make Beijing a "15-minute-city"--allowing people to access most essential services within a 15-minute walk. This could reduce overall service costs to the city and provide viable alternatives, such as walking, bicycling, and public transport, to the use of a car. A number of cities, including Chengdu, Melbourne and Paris, have incorporated this idea into their planning[xliv].

### *2.1.4 Strengthening consumer demand management.*

Encouraging customers and industries to participate in decarbonization initiatives can help cities meet their targets. Here are two high-potential possibilities.

*Advocate a low-carbon lifestyle*. For large-scale decarbonization, consumers need to embrace going green. In the last ten years, Beijing residents have become more aware of environmental issues, including air pollution, clean water and climate change. To build on this, the city could work with companies to enable consumers to decarbonize their lives. Ant Financial, for example, launched the Ant Forest Program in 2016. The digital program builds a scoring system based on how environmentally friendly a purchase is, such as buying a metro ticket instead of fuel for a car. The scores allow users to grow virtual trees and compete with friends. The popular program, which has 200 million users, has cultivated long-term behavioral change in purchasing decisions, including reducing plastic bag usage.

*Put "circular economy" principles into action.* A circular economy means shifting resource consumption from linear flows—raw materials to assembly to consumption to disposal— to circular flows in which materials are repeatedly re-used. For example, Beijing produced 10 million tons of residential waste in 2019. This waste could instead become useful production inputs through effective recycling. Shifting to circular economy principles could help ensure that efforts to control direct emissions are not compromised by greater indirect emissions from increased consumption. One short-term step is for the government to work with industries to scale up the use of recycled waste. There is private-sector interest in this idea—Alibaba has created Xianyu, a robust secondhand market. JD helps consumers to recycle old clothing and mobile phones, and Meituan, a food-delivery and consumer-service platform with 240 million users, has set up a pilot to collect used tableware.

**2.2 Innovation: How Beijing can orchestrate the development of next-generation low-carbon technologies**

For hard-to-abate sectors, such as power, steel, oil, and gas, 30 to 70 percent of emissions can be addressed through current policies and technologies. The rest will need to be addressed through new and developing technologies.

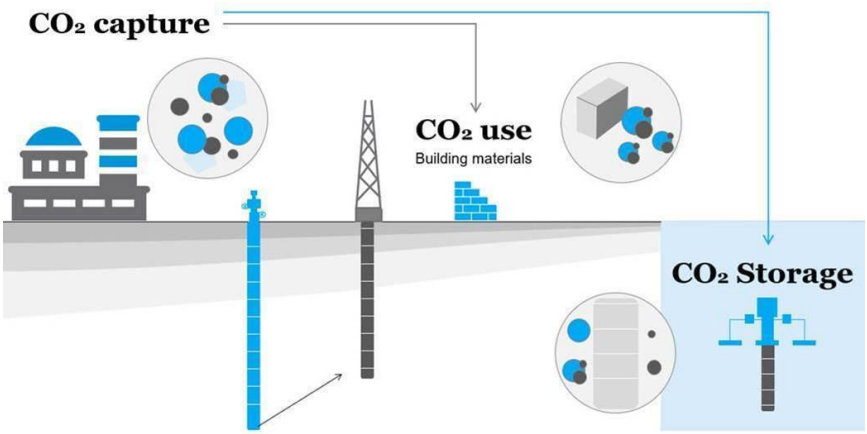
An emerging technology normally goes through three stages before mass adoption: concept development, early experimentation, and scale-up. Government support can help companies in the latter two stages. Solar panel technology, now a mainstream green technology in China, is one example. Due to high costs, the development and adoption of solar power was slow before 2000. With strong government support since then, the solar PV industry in China has advanced rapidly, improving the economics. Today, the cost of solar PV is sometimes competitive with fossil fuels, even without subsidy.

With that example in mind, what could be next? AVs are one possibility to put on the fast track for experiment and scale up. From an emissions perspective, the main potential benefit of autonomous technology is to improve traffic flow. In addition, the deployment of AVs, in conjunction with ridesharing, may remove the need to own a car. That could mean fewer, more efficient cars on the road, improving both emissions and congestion. Nevertheless, AVs are unlikely to achieve the critical mass needed in the near future. In the meantime, data collection from AV pilot programs will be essential to understand their potential impact on traffic and safety and to devise the best strategies for deploying AVs.

Two other technologies—CCUS and hydrogen—could go a long way to complete the last mile of reducing emissions in the energy system. They are both promising enough to be put on the fast track to development (see sidebars on CCUS and hydrogen).

***SIDEBAR: The role of carbon capture, utilization and storage (CCUS) in a low-carbon future***

*Carbon capture utilization and storage (CCUS) refers to capturing CO2 from large stationary sources, such as power plants or industrial facilities, then either storing that CO2 or using it to make other goods. Because the CO2 never reaches the atmosphere, CCUS could play a significant role in emissions-reduction. The power and industrial sectors contribute as much as 70 percent of China's emissions.*



*China has sizeable coal reserves and some regions rely heavily on it. Coal, however, is both polluting and emissions-intensive. The application of CCUS to coal assets could make it a much lower-emission source of power. According to McKinsey research,[xlv] CCUS could capture about 1.3 billion tons of CO2 in China by 2050.*

*That is the potential.*

*In reality, there are two major issues. First, there is cost. Even with subsidies, the cost of CCUS--450 RMB per ton of CO2 abated-- is too high for wide industrial use. With effective policy support, that cost could fall substantially, as economies of scale kick in. Second, the CCUS industry does not yet have a clear business model: even if it becomes less expensive, how does it make money? Right now, CCUS is simply an additional cost for both the capture facility and the storage facility. One possibility is to treat CCUS as a utility funded by government. Another is to establish a carbon market with a price that is higher than that of CCUS to incentivize businesses to reduce CO2 emission using CCUS.*

***SIDEBAR: The role of green hydrogen in a low-carbon future***

*Green hydrogen is produced through low-emissions technologies, such as electrolysis, and is powered by renewables. ("Grey hydrogen" uses fossil fuels, through energy-intensive processes such as coal gasification or steam reforming. "Blue hydrogen" is somewhere in between; it is created when CO2 is sequestered via CCUS.) Hydrogen only emits water when burned and can be made without releasing CO2.*

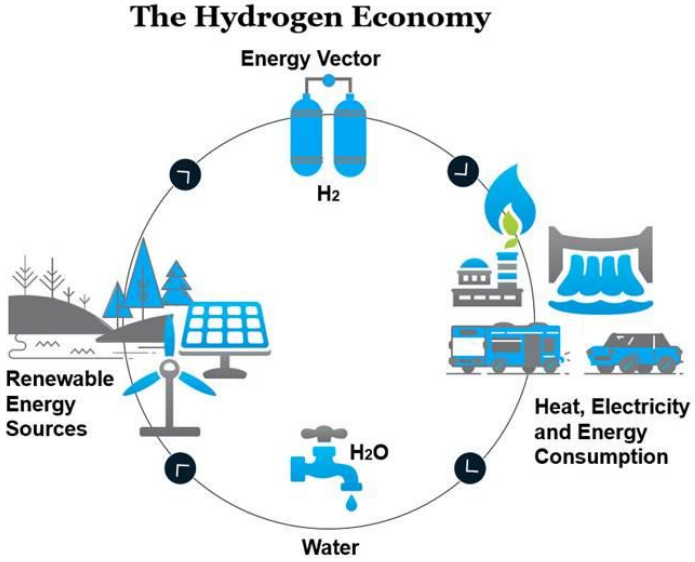
*Hydrogen could be used in place of the fossil fuels that currently provide about four-fifths of the world's primary energy supply—and which are responsible for the bulk of GHG emissions. According to McKinsey research, hydrogen demand in China could rise from next to nothing now to 18 million tons by 2030, primarily in the steel and transportation sectors.*

*In the steel industry, hydrogen could replace coal as a reducing agent in iron-making. For the transportation sector, hydrogen fuel-cell vehicles could play a role in replacing the gas-powered internal combustion engine. The potential is high, especially in long-distance transportation including aviation, buses, and trucks, as most EVs have a range of less than 600 kilometers range and take longer to charge.*

*As the price of hydrogen technology falls, other uses, such as residential heating, also become possible. Given the high cost to transport hydrogen from overseas, China is expected to meet demand with domestic supply. This could enable it to take a leading role in the development of hydrogen technology, as both market and producer.*

*To realize the full potential of hydrogen, however, more infrastructure needs to be built, such as pipelines and hydrogen-fueling stations, to resolve the mismatch between supply and demand. Renewable energy-rich regions, such as the southeast and Inner Mongolia, are better suited to produce green hydrogen – but demand is likely to come from the northeast and coastal regions. Hydrogen pipelines could solve this problem.*

*In addition, to create and meet urban demand, storage and hydrogen-fueling*




*stations will be needed. At least at first, city, regional, and national governments might want to take the lead, as the cost is likely to be high and the market uncertain. That is what Germany is doing; in 2020, the country announced a plan to invest €9 billion to build hydrogen infrastructure as part of its decarbonization plan.*

*Another priority is to get the market going. To do so, incentives may be required to generate initial demand. Hydrogen technology is improving fast and costs are coming down. One high-potential area is hydrogen fuel-cell electric vehicles(FCEVs). Beijing is home to a complete hydrogen value chain, including production, storage, transportation, and vehicle manufacturing. It has also started to construct a hydrogen industrial park, specializing in vehicle development. In the future, Beijing could carry out demonstration projects in key applications as a way to attract new investments.*

*Even so, hydrogen has to be considered a work in progress, and the economics are still daunting. For example, FCEVs are encountering problems with high battery*

*cost and hydrogen storage safety. Progress has therefore been slow, and to reach its potential, hydrogen may need more substantial government support than it has gotten so far.*

***END OF SIDEBAR***

Bringing next-generation technologies to scale will call for collaboration among the government, industry, private investors, and research institutions. The Beijing city government could become something like a conductor to orchestrate this effort.

It could start by articulating how it sees the role of new technologies such as AVs, CCUS and hydrogen, in its long-term decarbonization vision. Then it could set out short-term targets (such as the recent announcement of a plan to get at least 10,000 hydrogen cars on the road by 2025), to activate the skills and imagination of the private sector and research institutions. Beijing's leaders could also design policies and set standards in order to create a safe space for industries to pilot CCUS and hydrogen projects. For example, legislation on how to store and transport CO2 could reduce the legal risks for the CCUS first movers.

To lower the cost of deployment, technology improvements in CCUS and hydrogen are necessary, and with its world-class talent, Beijing is well placed. Tsinghua University and Beihang University are leading researchers in hydrogen fuel cell technology. In addition, Beijing-based oil-and-gas companies have started to invest in hydrogen and CCUS projects as part of their low-carbon strategy.

Beijing can also work to cultivate a supportive startup environment for new technologies. One way to do so is to create government-sponsored innovation labs where entrepreneurs can share their ideas with each other and with policy makers. Israel, which is already known for its innovation culture, has established a $4 million innovation lab in northern Haifa that will focus on environmental technology. In a joint government-industry initiative, in 2017, Sweden set up three clean-tech hubs—to research ways to decrease GHG emissions and increase energy efficiency and security.[xlvi]

Once an experiment is proved, Beijing can support the private sector in bringing these innovations from pilot to market, by carrying out demonstration projects or making them a priority for public procurement.

## Section 3. How Chinese cities can foster regional and global decarbonization

Cities have all the necessary attributes—talent, money, size, and influence—to become a market-oriented green technology innovation leader. To do so, it needs to act both regionally and globally.

On the regional level, cities can encourage and support decarbonization of its corresponding region. Here are four possible actions.

***Promote regional green infrastructure.*** Cities could use its buying power to buy cleaner energy from surrounding areas. Renewable energies such as solar and wind power are intermittent. To generate electricity continuously, they need to be paired with energy storage, which makes the whole system more expensive than a traditional thermal power station. Major cities could work with neighboring governments and power generation companies to improve the economics, for example by signing long-term power purchase agreements (PPAs) and agreeing to higher purchase prices for renewable energy.

There are working examples of such efforts. In 2015, Washington DC signed a power-purchase agreement (PPA) to buy the entire output of a 46MW wind farm in Pennsylvania[xlvii]; this will cover 30 to 35 percent of the city's electricity demands. In 2020, the City of London, the neighborhood that includes London's financial district, signed a PPA to purchase 49.9 MW of power from a solar farm in Dorset, projecting to power half of its electricity demand.[xlviii] The guaranteed revenues will support the construction of the facility, and is projected to save the City £3 million in energy costs. Similarly, Sydney entered into a 10-year PPA to purchase wind and solar from New South Wales region.[xlix]

***Adopt regional emissions accounting*.** The traditional measurement of GHGs accounts for emissions within the city limits. But many of Chinese cities' emissions are released elsewhere, in the form of the food, goods, and services produced but used by residents. Consumption-based GHG counts these emissions. By adopting this standard, the cities of China would have a better sense of where their emissions are coming from and thus how to lower them, whether through consumer education, public procurement, or other strategies.

***Upgrade regional industries*.** As China's service industry has been gradually overtaking manufacturing to become the largest sector of the economy, there are growing calls for stepped-up efforts to develop this "pillar industry." Cities can help their surrounding areas, especially provinces with high-emission industrial sectors, with industry upgrades. Hebei province, for example, is experiencing rapid development. In 2020, high-energy-consuming industrial sectors, including steel, chemicals, and equipment manufacture, accounted for 40 percent of Hebei's economic output. Hebei consumes about 7 percent of China's energy, while contributing only about 4 percent of its GDP. With coal the primary source of power (about 75 percent of consumption),[l] industrial decarbonization should be the priority—a matter in which Beijing has considerable expertise.

***Share best practices and policies.*** Many major cities such as Beijing, Shanghai and Chengdu are ahead of much of China in terms of setting (and meeting) decarbonization targets and establishing a legal framework for carbon management. This is expertise they could share—and even make standard—with the region. In addition, cities like Beijing have already made the transition from a heavy-industry dominated economy to one in which the service sector is more important. The city is well-positioned to help regions make this adjustment, too. Decarbonization does not come without difficulties, such as higher costs and short-term unemployment. Cities can use their education resources to prepare workers for new kinds of jobs. This could take the form of developing online training classes or opening regional campuses. Germany has done something like this; to ease the transition to becoming coal-free by 2038, the government has established a $45 billion package to support the closure of coal assets in major coal-producing states and to reskill the sector's workers.[li],[lii]

On the international level, cities have the practical and financial expertise, as well as the global standing, to play an increasingly important role in promoting decarbonization and setting climate policy. Here are three ways they can do so.

***Mobilize capital for green projects.*** Cities like Beijing are already well on the way to becoming China's green finance center. The Beijing Environmental Exchange, which runs the city's carbon exchange, has logged in more than 1,200 green projects since 2019. The initiative has also formed partnerships with more than 20 banks, insurance companies, trust companies, securities, funds, industry associations, and third-party assessment companies.

Going forward, cities could work with regulators, private investors, and research institutions to define and implement a set of criteria for what comprises a "green" financial product, as the EU Taxonomy Regulation has done. The Peoples Bank of China, for example, has started drafting a Green Bond Standard in 2020, and other international financial institutions are creating green-investment indexes.

Cities can also encourage low-carbon investment by fostering partnerships with financial institutions—whether public, private, or multilateral—that have shown interest in green bonds and other kinds of investment. For example, by 2025, the Asian Infrastructure Investment Bank aims to direct half of its financing to climate-related projects. AIIB is also participating in a $500 million Asia Climate Bond Portfolio that aims to accelerate climate action and address the underdevelopment of the climate bond market.

***Work with partners to create innovative demonstration projects*.** Singapore's Tengah[liii] project, started in 2016, is a 42,000-home town under development that is both green and smart, with a no-car business district, automated waste collection, centralized cooling, an app that allows residents to monitor their energy and water usages, and a 328-foot-wide ecological corridor as a safe passage to wildlife. Tengah demonstrates that when a government makes a commitment to sustainable urban design, results follow. Cities in China can keep an eye on Tengah, and learn from its practices.

***Support high-level discussions and collaboration*.** Without strong, consistent international collaboration, developing a low-carbon and environmentally resilient future will not be possible. As major emitters, and given their economic and organizational strengths, cities such as Beijing, Chengdu, Dalian and other C40 member cities could offer to host future climate meetings. They can perhaps even carry the baton from Glasgow, Scotland to be the next city to host the UN Conference of the Parties (COP) in 2022[liv] and to take a more active role in convening international discussions. They could also take the lead in fostering a specifically Asian approach.

## Section 4: Cities at work: The role of the public and private sectors in urban decarbonization

Cities will be a critical force in decarbonization, but they cannot do it alone: national governments and the private sector also need to step up.

**4.1 The public sector: Working with stakeholders to build resilient and sustainable cities**
Decarbonizing cities will have to be a team effort. One useful role for governments, whether local or national, is to bring the stakeholders together, so that they are all pulling in the same direction.

***4.1.1 Build mechanisms for public-private collaboration.***

One form of government clout is the power of its purse; embedding environmental standards into public-private partnerships and giving preference to projects that demonstrate emissions-reduction potential would be powerful incentives for builders and others to get serious about decarbonization.

Because government is central to all parts of the urban economy, it is in position to take the lead in working with the private sector and other partners on initiatives to promote renewable energy, autonomous vehicles, and other green innovations. For example, a public-private investment fund could establish what projects to prioritize, test them, and then work to scale up the successful ones. Local governments could establish incubators—physical and digital spaces in which entrepreneurs, academics, and scientists can share ideas.

Finally, business, social, and government entities can work together to promote sustainability norms to the public, and to achieve specific goals. One initiative to watch is the Global Plastic Action Partnership (GPAP), a collaboration of governments, businesses, and NGOs launched in 2018 that aims to eliminate plastics from the ocean. There is real action taking place, with Indonesia testing a broad-based approach and passing relevant legislation with the goal of reducing ocean plastics 70 percent by 2025.[lv]

***4.1.2 Promote green finance***

The environment cannot be separated from economics. China recognizes this; in fact, it has defined high environmental standards as one of its five development priorities. Its efforts to promote diversified green investment and to build a national carbon market are two examples of green economics in action. But more will need to be done. China is expected to require $424 billion to $566 billion in green investment a year to achieve China's environmental pollution control goals and the international commitment of peaking carbon emissions by 2030.[lvi] Green bonds, a type of fixed-income instrument that is specifically earmarked to raise money for climate and environmental projects, are an ideal financing tool to support the required investment due to their relatively simple structure, low additional cost and transparency requirements. The Chinese government's endorsement of green finance and green bonds may help green bond issuers to reduce issuance costs or to obtain financial subsidies. Some provincial governments already have subsidy programs in place, and a single issuer can apply for reimbursement up to $848,000[lvii]. In this case, it would be most efficient if the national government were to set market standards, including defining what constitutes a green financial product and establishing regulatory reporting requirements.[lviii]

In 2021, China launched a national carbon market, with the goal of reducing greenhouse gas emissions. For now, the emissions trading system covers China's power industry and roughly 2,000 energy generation facilities. That alone represents 30% of the nation's total emissions and over time the trading system will encompass heavy industry like cement, steel, aluminum, chemicals and oil and gas.[lix] The government can strengthen the national carbon market by further mobilizing private investment for mitigating actions and achieving cost-

effective abatement. To realize the full potential of the carbon market, China could further promote the use of carbon credits (often referred to as "offsets"). Promoting China Certified Emission Reduction (CCER) products as offset credits and incorporating them in the national carbon market is a good start towards accelerating the broader transition to a lower-carbon future. So far, the Chinese government has validated 2,856 CCER projects and registered 1,047 CCER projects. If done successfully, the China GHG Voluntary Emission Reduction Program can share its learnings and solutions with other countries globally to accelerate emission reduction.

#### *4.1.3 Build long-term resilience and a green recovery.*

Governments could prioritize stimulus programs that entice private-sector participation and those that put green initiatives at the forefront. Taking infrastructure stimulus as an example, one way to stretch stimulus dollars as far as possible is by deepening capital markets and developing incentives for the private sector to play a bigger role in infrastructure financing. One way to do this would be creating an enabling environment for public–private partnership investment. Government stimulus programs can take this as an opportunity to direct public and private funding toward sustainable, resilient, green infrastructure—accelerating progress on shoring up infrastructure vulnerable to climate change. For instance, initiatives can aim to assess an issuer's level of alignment with the objectives of the Paris Climate Agreement: climate-change mitigation, adaptation, and low-carbon transition. [lx] The Chinese government could consider inviting more private sector players to jointly carry out projects in decarbonization-focused areas such as new electrical vehicle charging stations and data centers. The stimulus program could also consider prioritizing carbon-intensive regions such as Shanxi and the Northeast for development funding to accelerate overall carbon emission reduction.

### 4.2 The private sector: Embed sustainability into strategy and work

Once governments enact a clear and stable regulatory environment, the private sector knows what is expected, and can even accelerate its contribution to decarbonization. We believe that sustainability will be a competitive advantage; companies that move fast to discover and adopt sustainable business models will have an important edge.

#### *4.2.1 Set a decarbonization strategy*

This strategy should be both specific and public, both to convey the company's commitment and to signal its intentions to the capital markets. After setting up the strategy, businesses can consider how to decarbonize operations. One possible approach is to participate in voluntary carbon markets to hunt for cost-effective way to reduce emissions.[lxi] According to the World Economic Forum, readily available and affordable practices ($12 per ton of CO2 equivalent), such as investing in circular economy practices and renewable power, could cut supply-chain emissions as much as 40 percent, at low cost.[lxii]

A number of international oil and gas companies have gone in this direction, announcing ambitious targets to reduce emissions throughout the lifecycle. With a defined target, and by evaluating scenarios based on different possible prices for carbon, they are better able to understand the risks and opportunities. On that basis, they are prepared to restructure their portfolio as circumstances change.

#### *4.2.2 Review how work is done*

The use of technology, digitization, and new forms of work sped up during the pandemic—and there is no going back. McKinsey has estimated[lxiii] that in advanced economies, 20 to 25 percent of the workforce could work from home between three and five days a week without loss of productivity. That could bring big changes in where work is done, and thus in travel-related emissions, and could raise interest in the idea of the "15-minute city," in which residents can fulfill their basic needs within a 15-minute walk from home. Additionally, COVID-19 has accelerated the shift in labor demand. Business leaders and governments can work together to incorporate climate risk awareness and decarbonization into reskilling efforts.

#### *4.2.3 Apply advanced capabilities*

Data quality and transparency is critical for companies to count, monitor, and reduce GHG emissions—and fast-improving capabilities such as big data, artificial intelligence (AI), and automation can help. Indeed, used well, they can do much more. Big data, for example, can help corporations use resources better; automation can make operations more efficient (and thus less emissions-intensive); AI can map projects and enable employees to become more aware of how to "green" their decisions.

□ □ □

Several major trends are likely to be part of the future. One is that people will continue to move to cities; by 2050, more than two-thirds of the world's population (68 percent) will live in urban areas, according to the United Nations. China's cities alone will add an estimated 255 million new residents.[lxiv] Another is that the Chinese economy will continue to grow. That is a good thing for its people, but does add stress on natural resources. And a third is that awareness of environmental issues, including climate change, is growing—both within China and around the world. City leaders, businesses, and residents will need to work together to deal with the challenges these trends present.

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