CHINA'S NEXT OPPORTUNITY: SUSTAINABLE ECONOMIC TRANSITION

How Jing-Jin-Ji Can Lead the Way

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The wind-rich region of Zhangjiakou in Hebei Province, pictured here and on the cover, features rolling green hills scattered with windmills. As of September 2015, Hebei has 9GW of wind installed, out of a national total of over 105GW as of mid-2015.

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China's Next Opportunity: Sustainable Economic Transition

How Jing-Jin-Ji Can Lead the Way

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A coal power station at night in China; the country's shift to a more diverse, low-carbon and innovative economy will lead to reduced carbon emissions - which contribute to both air pollution and climate change.

FOREWORD

Dear Reader,

I believe that the U.S.-China relationship is the most important bilateral relationship in the world, and it is critical that we work together to solve the world's most important problems. One of our greatest challenges is how to pursue a new economic growth model that takes environmental sustainability into account. In China in particular, air pollution is affecting health and quality of life today, while climate change threatens the nation's future. These are not purely environmental challenges; they pose a critical threat to China's economy and long-term prosperity.

That's why I am so pleased to share the results of this Paulson Institute paper, "China's Next Opportunity: Sustainable Economic Transition." The paper makes the case for a truly sustainable economic growth strategy for China, one that takes air quality and climate change into account as part of a larger strategy aimed at diversifying China's economy away from its historic dependence on heavy industry. We focus specifically on the Beijing-Tianjin-Hebei region (also known as Jing-Jin-Ji), which is home to growing cities, fast-urbanizing suburbs and rural areas, and core industrial strongholds like the steel powerhouse of Hebei Province. The paper presents an overview of this region and its need to move to a more sustainable economic growth strategy, with particular emphasis on those industries that are the largest current contributors to the region's emissions profile.

Overall, this initial paper in our Jing-Jin-Ji series confirms that a sustainable economic transition is not only necessary, but also entirely achievable for this region. Just as China is now taking the lead in many areas of clean energy technology today, the Jing-Jin-Ji region has the potential to play a leadership role in showing how to help existing industries like those in Hebei become more efficient and cleaner, while also attracting new renewable and efficient energy technologies as tomorrow's economic drivers.

We do not approach these issues through rose-colored glasses. We acknowledge that many aspects of China's sustainable economic transition are challenging, especially for local leaders in cities currently powered by heavy industrial growth. But we also point to lessons from U.S. cities that have overcome industrial decline through economic development strategies that focus on a more diverse industry mix, including clean technology manufacturing and deployment.

This is just the beginning: in the coming year, the Paulson Institute will provide in-depth analysis of specific industry sectors in the Jing-Jin-Ji region, along with specific recommendations for transition strategies for these sectors. In doing so, we will continue to build on our strong relationships with Chinese and U.S. leaders and experts who are already developing real-world solutions to the particular challenges faced by leaders in the Jing-Jin-Ji region.

At the end of the day, we believe that this paper and its conclusions can serve as the basis for deeper understanding and cooperation between the U.S. and China. Nothing reinforces the benefits of cooperation more than jointly tackling the environmental and economic challenges that affect us both. With this paper, we invite you to join us in that journey, towards a more stable and prosperous future.

Sincerely,

Henry M. Paulson, Jr.
Chairman

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Modeling Review

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Chinese Case Studies

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Photos

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CONTENTS

INTRODUCTION AND EXECUTIVE SUMMARY

As short-term air quality and long-term climate risks come into focus for China, there is a clear need for an economic transition that allows the country to shift to a more diverse, low-carbon, and innovative economy—in other words, a more economically and environmentally sustainable economic growth model. And because China is the world's second largest economy and largest emitter of carbon dioxide, its development decisions have far-reaching implications. [1]

With this paper, we outline a vision for a sustainable economic transition in the Jing-Jin-Ji region, which we hope will ultimately inspire a similar transition across China.

The Paulson Institute defines sustainable economic transition as an economic and industrial move away from polluting, heavy industry to development that is low-carbon, resource efficient, diversified to include service-based industries, and supported by a talented workforce to drive new innovation. Such a transition is closely in line with both China's economic and environmental goals, and consistent with national air quality targets and evolving national efforts to combat climate change. For example, the 12th Five-Year Plan (2011-2015) called for a more strategic approach to development, efficient use of resources and prioritization of low-carbon growth—a theme that will likely be reemphasized in the upcoming 13th Five-Year Plan (2016-2020).

Similarly, China's 2013 Action Plan on Air Pollution Control and Prevention established a framework for addressing air pollution, with a particularly detailed series of steps and objectives for three important regions, including the Beijing-Tianjin-Hebei region, or Jing-Jin-Ji. [2] The nation's 2014 climate change plan detailed China's commitment to low-carbon development by spelling out a new national program for reducing carbon intensity and capping CO_2 by 2030 [3] —a plan that was formalized through China's Intended Nationally Determined Contribution (INDC) to the United Nations Convention on Climate Change, released in June 2015. [4] As China faces increased pollution, rapid urbanization, and economic pressure to diversify its industries away from a heavy manufacturing base, the country is prioritizing an economic transition that can address all these issues and serve as a model for other nations.

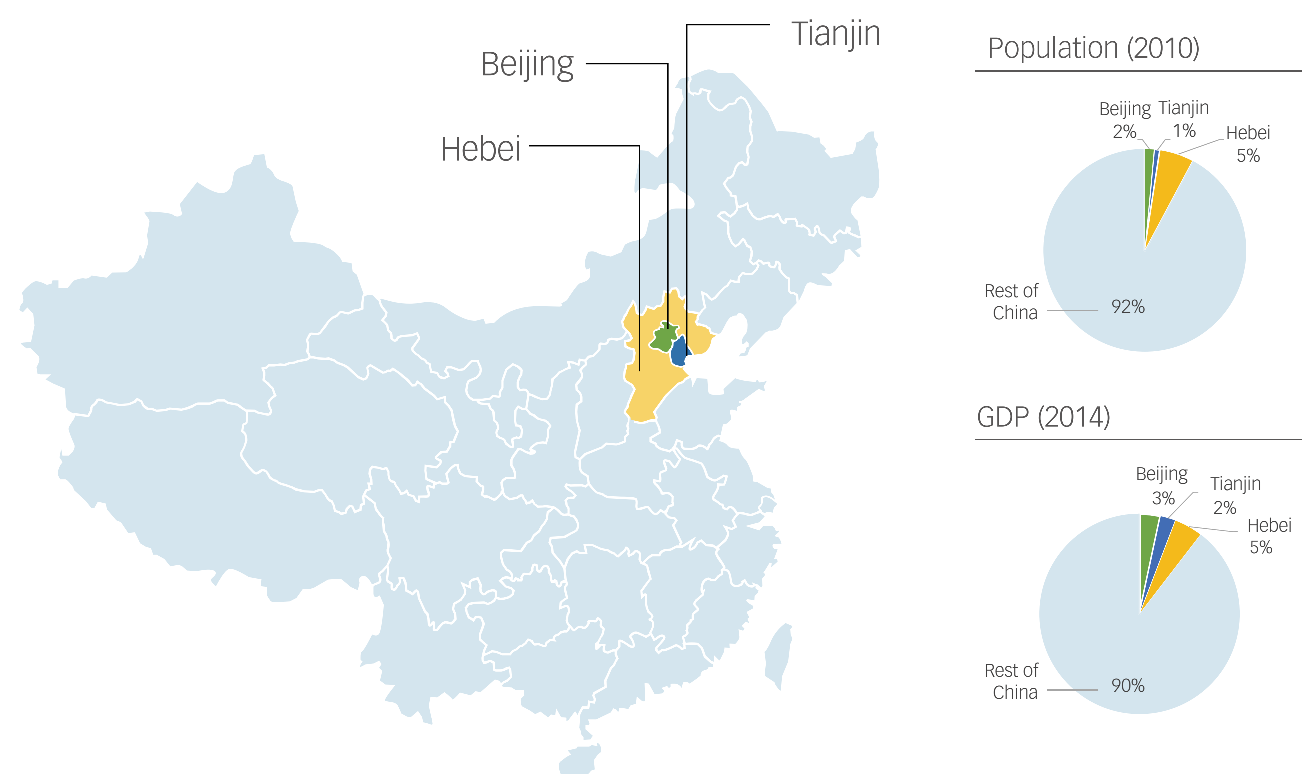
China's Jing-Jin-Ji region presents a compelling opportunity to highlight the opportunities—and the challenges—in transitioning to a more sustainable economic growth model. Located in Northern China, the Jing-Jin-Ji region is a rapidly developing economic cluster with a population of 130 million that accounted for roughly 10% of China's annual GDP in 2014. [5] More recently, the Chinese government has prioritized Jing-Jin-Ji regional economic integration to spur development. [6] The region is diverse, including areas of intense industrial activity, modern urban centers, and edge districts trying to resist urban sprawl and maintain a rural character. Jing-Jin-Ji's Hebei province, home to some of China's largest steel and iron manufacturers, and to some of the most polluted cities in the world, is a key focus of the Chinese government's industrial efficiency improvements and air quality control.

Given its diverse economic mix, strong policy and regulatory environment, and central location in China, the Jing-Jin-Ji region has the potential to dramatically reduce emissions and set the tone for China's nationwide transformation toward a more sustainable growth model. Changes already taking place in the Jing-Jin-Ji region are just a microcosm of what will soon begin happening nationwide if on-the-ground implementation matches up to government aspirations.

With this paper, we outline a vision for a sustainable economic transition in the Jing-Jin-Ji region, which we hope will ultimately inspire a similar transition across China. The paper presents brief illustrations of cases in the U.S. and China where such transitions are already underway and have created new jobs and industries, and lays the groundwork for future in-depth analysis from the Paulson Institute of how a similar transition might occur in the Jing-Jin-Ji region. Through such illustrations, the report underlines a broad theme: **a strong policy framework can inspire private sector innovation and investment, and together they create a foundation for a sustainable, productive, and prosperous economy.**

Section 2 of the paper reviews macro-level factors that show how economic transition and environmental quality can go hand-in-hand for China at its present state of development. Decades of experience in other countries

JING-JIN-JI IN RELATION TO CHINA: LOCATION, POPULATION AND GDP



Beijing, Tianjin and Hebei together hold 8% of China's population and produce around 10% of national GDP.

Source: National Bureau of Statistics, 2014 suggest that intelligent policies can enable higher-quality growth that is consistent with both environmental and economic goals. (In our earlier paper *Climate Change, Air Quality and the Economy,* we outlined ways in which national policy and enforcement could be improved to achieve this result.)

A detailed analysis of emissions, air quality and energy efficiency data in section 3 concludes that industrial transition is key to cleaner air and lower CO_2 emissions—and that this transition can be accomplished in part through industrial upgrades and energy efficiency. Section 3 goes on to summarize the steps that cities and businesses in Jing-Jin-Ji are already taking to transition to more sustainable growth models. Many cities in Jing-Jin-Ji are face-to-face with the harsh economic consequences of shifting away from overdependence on polluting, heavy industry like steel following long-term over dependence on this industry. Others in the region are at a relative advantage since they began diversifying their economies early by pursuing new and lower-carbon industries like solar and wind power development. The section contains the following policy suggestions:

- Based on the relative impact on ambient air quality and carbon emissions, environmental and economic officials should prioritize **reducing emissions and increasing efficiency in Jing-Jin-Ji's industrial and public heating sectors.**
- The government should **prioritize energy efficiency improvements within the iron and steel sector,** such as through deepening the Top 10,000 Enterprises program. While economic transition away from fixed-asset investment and the elimination of overcapacity in steel will naturally help reduce emissions, energy efficiency measures still have a large scope for reducing PM2.5 and carbon emissions from the iron and steel sector.
- Hebei should increase attention to policies that **promote renewable energy and energy efficiency,** since these two industries have strong growth and job creation potential.

Hebei should increase attention to policies that promote renewable energy and energy efficiency, since these two industries have strong growth and job creation potential.

Section 4 highlights case studies from the United States, where once-industrial cities and states have found a way to pursue economic growth while also addressing environmental and climate concerns. We focus on California and the U.S. Rust Belt cities of Pittsburgh, Cleveland, and Toledo. The section contains the following policy prescriptions:

- City officials must make early efforts to **identify new industries for growth,** rather than seek to revitalize declining industries and fuel sources. Rust Belt cities that recognized the need to diversify their economies early got a head start on those that concentrated on protecting jobs in legacy industries undergoing automation or downsizing.
- **Strategic investments in R&D,** tied through local institutions of higher education, can be an effective method for fostering new clusters of industry or services. In particular, cities should focus on identifying a strategic R&D focus, based on existing assets and infrastructure, as opposed to funding higher education overall or merely upgrading existing legacy manufacturing centers.
- **Integration of policy goals at the national, regional and local**

level is key to ensuring that environmental and economic prosperity go hand in hand. By taking a leadership role in setting and enforcing strict environmental standards and energy policy goals, regions can encourage innovation and foster new industries.

While the cases in the U.S. occurred in contexts very different from China, all have important lessons for policymakers considering how to minimize the potentially negative short-term after effects of economic transition.

2. IMPROVED ENVIRONMENTAL PRACTICES ARE NECESSARY FOR CHINA'S ECONOMIC TRANSITION

China has reached a stage in its development where pollution is hindering economic growth.

2.1 A transition can help ensure clean, sustainable growth

China is slowing industrial growth and tapering investment in infrastructure to reduce overcapacity in steel, cement and glass manufacturing. These shifts are causing economic pain in regions that are overly dependent on manufacturing, including Jing-Jin-Ji's Hebei, but they are creating economic opportunities as China looks to emerging, lower-carbon industries including renewable energy and energy efficiency.

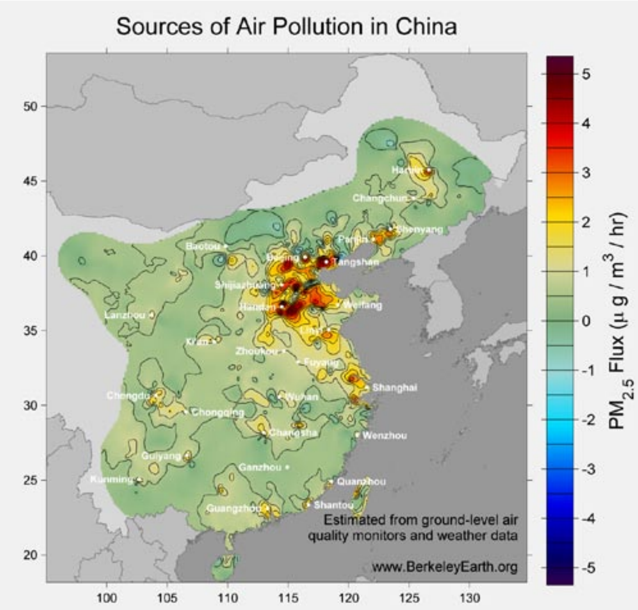
Despite a short-term economic slowdown, cities in Jing-Jin-Ji are identifying ways to take advantage of the economic shift by leapfrogging technologies, creating standards, and strengthening enforcement to move towards cleaner, higher-quality growth. The central government has also made important policy progress to support a sustainable economic transition, including incentives to promote renewable energy and energy efficiency. China's new Environmental Protection Law, coupled with improvements in local enforcement, is beginning to push the country's most industrial regions towards cleaner development models. Nevertheless, there are many opportunities to accelerate change. Chinese leaders and businesses should identify those areas where policies and private sector investment can have the biggest impact on technology deployment, cluster development and low-carbon economic growth.

2.2 Air pollution and climate change have significant economic impacts

China has reached a stage in its development where pollution is hindering economic growth. Conventional air pollutants like sulfur dioxide (SO_2) and nitrogen oxides (NO_X) – two major precursors to PM2.5 pollution – have near-term air quality implications, including health impacts that result in lost productivity and damaged ecosystems. Most large Chinese cities are experiencing levels of pollution far above those considered acceptable by international health standards: in 2014, only eight of China's 74 largest cities met national standards for air quality. [7] According to a 2014 study by Tsinghua and Peking University, ambient air pollution from coal consumption caused an estimated 670,000 excess deaths in China in 2012. [8]

Climate change and air pollution also have long-term social and economic implications. As a result of rising levels of carbon dioxide—a gas that can remain in the atmosphere for hundreds of years—China faces enormous risks from climate change, including increased extreme weather events, and more frequent and longer droughts affecting the country's food supply and rural economy. China's low-lying coastal areas, home to as many as 60 million

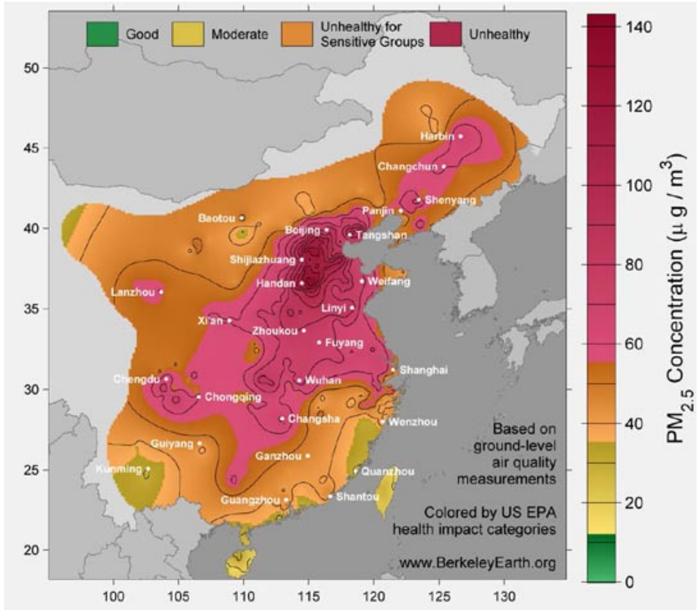
SOURCES OF AIR POLLUTION IN CHINA



Source: Berkeley Earth, 2015

Sources of PM2.5 air pollution are concentrated in and around the Jing-Jin-Ji region.

NATIONWIDE AMBIENT PM2.5 CONCENTRATIONS



Source: Berkeley Earth, 2015

While the highest emissions of PM2.5 are concentrated in the Jing-Jin-Ji region, the impact of those emissions is nationwide.

people, are particularly vulnerable to flooding from climate change. [9] Among the reasons why China must prioritize a cleaner environment, along with the obvious public health and quality of life issues, is the country's need to attract and retain a talented, global workforce. While Chinese educated abroad are returning in large numbers, the statistics show the movement is not just in one direction. According to Chinese Ministry of Education statistics, in 2013 over 350,000 overseas Chinese returned to China, a steady increase versus just 69,000 in 2008. But alarmingly, many returnees leave China again due to concerns about pollution, among other factors. In fact, up to half of new returnees may leave China again within six months. [10] A 2014 Hurun study of China's wealthy individuals—defined by Hurun as those with assets over US$ 1.6 million—found that 60% of high-income Chinese returnees were considering leaving the country for reasons of pollution, food safety, and education for their children. [11] In addition, recruiting firms frequently cite air quality as the top reason they have difficulty attracting global talent to China.[12] Foreign firms sometimes add a hardship premium or other benefits such as extra vacation to encourage people to locate in China, [13] in some cases, this premium is as high as 10% of base compensation. [14]

In the Jing-Jin-Ji region, there are clear signs that air quality is affecting the region's ability to attract and retain talent. Businesses are reportedly less likely to choose Beijing as a place to set up operations due to pollution,[15] in some cases because managers are unwilling to locate in China. Pollution is also affecting the relocation decisions of business owners already operating in China: A 2011 study by China Merchants Bank and Bain and Company showed that of Chinese business owners with over RMB 100 million, 27% had emigrated and 47% were considering relocation.[16]

Among the reasons why China must prioritize a cleaner environment, along with the obvious public health and quality of life issues, is the country's need to attract and retain a talented, global workforce.

Relocation decisions matter for China because of the critical role of human capital in the economic transition towards advanced technology and higher incomes. The desire of high-performing creative people to concentrate in a particular geographic region around business or economic activities, otherwise known as "clustering," is especially important in the era of global labor mobility. Trends suggest that oftentimes technology clusters form in places with strong cultural and natural amenities. Once a cluster forms, the region tends to benefit from knowledge spillovers within high-tech geographic areas. [17] While the Chinese market will remain a magnet for global talent in the short term because of its size and growth, evidence strongly suggests that pollution—especially air quality—increasingly affects relocation decisions. [18]

2.3 Tighter environmental standards can improve competitiveness

Strong policies and environmental standards play an important role in reducing emissions and promoting competitive low-carbon economic growth. While incumbent industries often argue that regulations hinder company growth, environmental standards can both foster innovation and give some companies a technology first-mover advantage over their peers. [19]

Stricter environmental standards and enforcement act in several ways that can improve industrial performance. The most straightforward is by encouraging innovation.

Stricter environmental standards and enforcement act in several ways that can improve industrial performance. The most straightforward is by encouraging innovation: In response to regulation, companies often increase R&D spending to bring down abatement costs, and reorganize production techniques to increase efficiency and reduce pollution. [20] A real-life example of such innovation comes from the U.S. electric utility industry, where tighter rules on sulfur dioxide in the 1990s encouraged companies to develop cheaper and more efficient scrubber technology as well as new fuel blends with lower emissions. [21] While it is arguable that spurring clean energy innovation limits investment in other fields—for example, higher global oil prices from 2005-2014 shifted auto R&D funding towards batteries and hybrids and away from improving conventional engines[22] —such shifts may catalyze entirely new technology pathways. A similar example from China is development of cleaner-burning vehicles and tailpipe emissions technologies at Dongfeng Nissan in China after new vehicle emissions standards were adopted in the 1990s and 2000s. [23]

The conventional view holds that looser regulation attracts industry, while tighter regulation causes industry to flee to "pollution havens." Indeed, China is sometimes portrayed as such a haven. At the country level, the evidence for this "pollution haven" theory is inconclusive compared to other factors such as labor and capital costs. [24] For example, in China's industrial northeast, heavily polluting industries initially thrived partly due to relatively low capital costs, fast construction times, and cheap financing terms available to state-owned firms—not so much due to lax environmental regulation attracting business from abroad. [25] The result has been overcapacity in domestic steel, glass and cement industries.

In contrast, tighter environmental regulations can actually spur innovation and help firms become more competitive as they invest in education, training, and early-stage research and development. [26] Such investments, including those in equipment modernization, can reduce labor and energy costs, producing long-term financial benefits.

Perhaps most important, regulations can give certain firms and regions a first-mover advantage in new technologies, products, and business models. Examples of this first-mover advantage abound: The Japanese auto industry in the 1970s gained a leg up in emissions standards, at the same time as European carmakers developed an advantage on safety. Refineries in Los Angeles upgraded technology in response to tighter local emissions standards in the 1980s, subsequently showing productivity gains and profits ahead of peers in Texas and Louisiana. [27] The case of Tesla in California also shows how environmental regulations, in this case a low-carbon fuel standard and targeted incentives for electric vehicle purchase combined with a cap and trade system for carbon emissions, catalyzed the creation of an electric vehicle manufacturing leader.

Smoggy Days: In 2014, only eight of China's 74 largest cities met national standards for air quality

2.4 China has reached a turning point in sustainable development

China is an upper-middle-income economy with the resources available to address environmental pollution. [28] As incomes rise, so do quality of life demands, and citizens, leaders, and businesses alike expect a cleaner environment. [29] China can take advantage of the work other countries have done to develop and commercialize technologies to address air pollution, and can also become a model for other countries in its ability to scale up technology deployment and sustainable growth strategies. While structural factors in the country's energy system, such as the predominance of coal-derived energy and the relative lack of domestic natural gas, work against rapid change, China is already taking the lead in transforming its energy system towards a cleaner, low-carbon model.

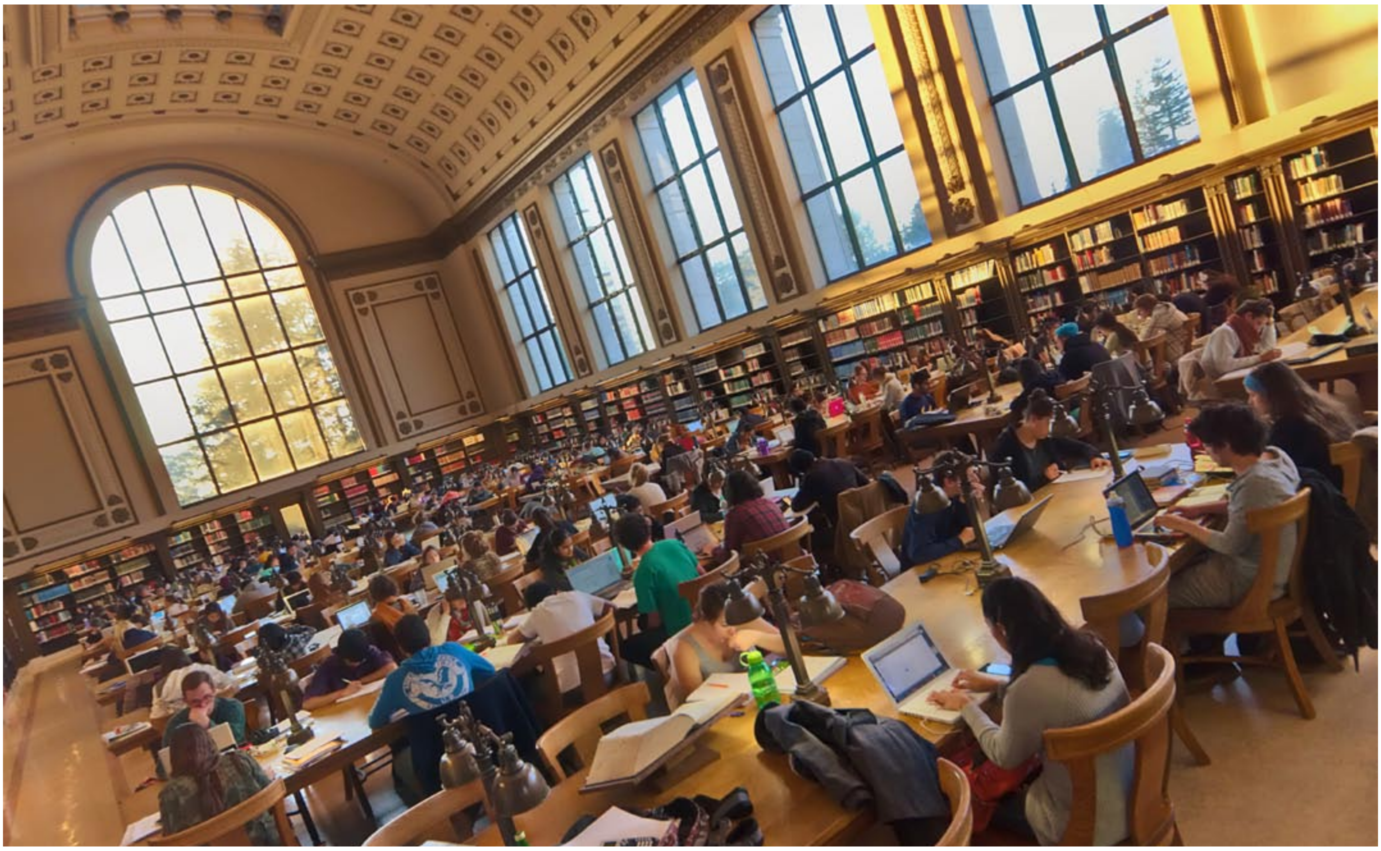
We believe China is at a stage where it has the financial resources and the access to technology to research and adopt air quality solutions that have been developed and applied in the industrialized world. Economists in China generally support this viewpoint, and agree the country has reached the per capita income threshold where it should begin to see improved environmental quality as the economy continues to grow, a concept frequently referred to as the Environmental Kuznets Curve. [30] According to a 2012 Tsinghua University study, because of increased environmental and scientific awareness, as well as technology learning from the U.S. and other advanced countries, the income level at which the country begins reducing environmental pollution could actually be lower for China than other countries. [31] China is already feeling the benefits of adopting advanced technology solutions. For example, as a result of supportive domestic policies, solar manufacturing in China has driven down the cost of solar, spurring global demand for solar photovoltaic (PV) panels,[32] while creating jobs and clean energy at home.

2.5 China's current policies provide a framework for sustainable economic transition

The Chinese government is already building the policy framework to support a sustainable economic transition. Today, China seeks to become a prosperous, technologically advanced country with a high rate of innovation by pursuing advanced, environmentally friendly industries while upgrading old-line industries. In addition to advanced technology, government policies emphasize innovation, sustainability, and talent development. Top leadership has chosen multiple channels through which to communicate these goals, including at central planning meetings as well as more publically through media channels.

Government leaders most recently reinforced their intention to develop China into an "ecological civilization"—a term the communique defines as "environmental sustainability, resource efficiency, and pollution mitigation"—at the 3rd Plenum of the 18th Communist Party of China (CPC) Central Committee. At the event, the government announced several major goals, including China's commitment to allow markets to play a more decisive role in resource allocation, together with stronger environmental and energy policies.[33]

Stated government policy is moving China in the direction of a clean, low-carbon and innovative economy. Among its policy priorities, clean air is one of the top agenda items. The following section describes in further detail the importance of air quality improvements for China's sustainable economic transition.



Brain Drain: China is facing difficulty attracting foreign talent, and those educated abroad who return to China are leaving again in higher numbers.

Major China Central Government Policies Related to Economic Transition

Technology: China's 12th Five-Year Plan (2011-2015) assigned advanced technology a prominent role and identified seven strategic emerging industries for promotion: energy-saving and environmental protection, next generation information technology, biotech, high-end manufacturing, new energy, new materials, and new-energy vehicles. [34] Environment-related and low-carbon technologies are seen as important elements of China's economic transition. [35] As part of the transition from over-reliance on manufacturing, the country is also promoting a gradual shift towards a consumer and services economy. [36]

Innovation: Whereas previously China focused on technology catch-up, continued growth now depends on innovation. [37] Accordingly, China's 2006 Medium to Long-Term Plan for the Development of Science and Technology made promoting indigenous innovation a national strategy. [38] Premier Li Keqiang has spoken about China's efforts to promote innovation through increasing the role of the market and creating a more inclusive environment for entrepreneurs. [39]

Sustainable growth: In recent years, China's leaders have increasingly expressed the need to shift from pursuing GDP growth towards considering all aspects of economic well-being, including the environment. For example, President Xi Jinping in 2013 called on the government to pursue "solid and real GDP" and "efficient, quality and sustainable economic development." [40] In order to achieve its sustainability goals, China has emphasized the importance of a circular economy, a form of economic development that "aims at environmental protection, pollution prevention and sustainable development through conservation of resources, reusing, and recycling in order to minimize pollution from the source and reduce overall waste per unit output." [41]

Talent: China has laid out plans to become a "talent-rich country" by 2020, seeking to attract top talent from abroad, increase investment in human capital, and raise the share of human capital in economic growth. [42] The Ministry of Human Resources and Social Security released a strategy in February 2015 outlining steps China would take to develop talent to support local innovation and economic growth. [43] Innovation, technology development and skills training are a few key themes highlighted in the document.

These four areas—technology, innovation, sustainable growth, and talent—overlap in several regards: To become more innovative, the country recognizes the need to develop and retain talent. A rich talent base can help accelerate an economic transition to higher technology industries. And a clean, healthy environment is needed to support this transition and retain talent in the process. From these principles, it is clear that national-level policymakers do not view economic development and environmental protection as trade-offs.

3. INDUSTRIAL TRANSITION, CLEANER AIR, AND GREEN GROWTH

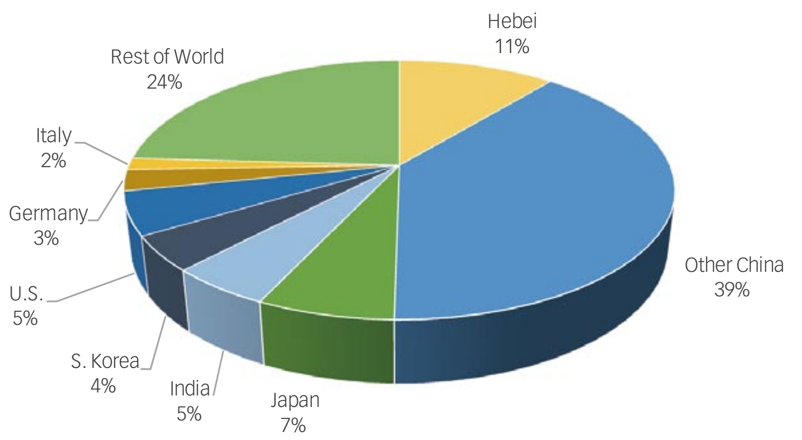
Today, the region has a bifurcated economic structure: While the urban economies of Beijing and Tianjin are relatively focused on services and government, the poorer province of Hebei is heavily industrial.

3.1 Industrial efficiency and economic transition are important starting points for Jing-Jin-Ji

Heavy industry has driven China through a remarkable three decades of economic growth. However, industry is also the largest contributor to air pollution, and is now hindering China's future development. China's steel, coke, and cement industries, for example, are the biggest contributors to conventional and greenhouse gas pollution nationwide and in the Jing-Jin-Ji region in particular. [44] In recent years the government has adopted strict measures to reduce reliance of high-emissions heavy industry, cut overcapacity, and minimize wasteful and inefficient manufacturing processes. [45]

The impact of these industrial efficiency and transition policies will be significant to the Jing-Jin-Ji region given that heavy industry is a core participant in the region's economy. Today, the region has a bifurcated economic structure: While the urban economies of Beijing and Tianjin are relatively focused on services and government, the poorer province of Hebei is heavily industrial. Primary and secondary industry accounted for 6% and 41% of Hebei's GDP in 2014, [46] and these industries accounted for roughly two-thirds of all employment in the province as of 2012. [47] The leading manufacturing industry in the province is iron and steel, with construction materials such as cement and glass also significant—these three industries alone accounted for roughly a third of the province's GDP in 2013. [48] Hebei is also the largest steel manufacturing province in China, accounting for 28% of the country's steel output in 2014[49] —the province produces more steel every year than the next largest steel producing country, Japan. [50]

HEBEI STEEL PRODUCTION



Hebei produces more steel than any individual country other than China itself.

Source: China Iron and Steel Association, 2014

3.2 Prioritize industrial emissions reductions and efficiency

China, and the Jing-Jin-Ji region in particular, has good reason to focus its pollution reduction efforts on efficiency improvements in the industrial sector, though efficient buildings and transportation are also important priorities. This conclusion is based on a Tsinghua analysis completed in partnership with the Paulson Institute to examine the relative impact of emissions reductions on ambient air quality in the Jing-Jin-Ji region in five broad sectors:* buildings, electric power, industry, transportation, and agriculture. [51] Tsinghua's analysis examined the impact on ambient PM2.5 concentrations of cutting emissions (all pollutants, including but not limited to primary PM2.5, which refers to particulate matter of 2.5 microns or smaller in diameter that scientists consider as most damaging to human health) individually from each of the five sectors in eight cities in the region. The model further analyzed the impact of emissions reductions in subsectors within the industrial sector, the largest emitting sector in the region as a whole.

Overall, modeling results show that reductions in industrial and building emissions (the latter mostly from heating) have the largest impact on ambient air quality. However, these results vary based on the city and season in which the reductions occur.** The results confirm the importance of taking both a localized (city level) and regional approach to air quality management, as well as the importance of considering seasonal factors.

Tsinghua's analysis reveals important details that can inform pollution reduction efforts during different seasons of the year. In the winter, when public heating is at its peak, a 30% reduction in domestic sector emissions has the largest relative impact on PM2.5 concentrations in most cities in Jing-Jin-Ji. The domestic sector includes residential and commercial public heating, cooking, and solvent use, but excludes electricity use. 95% of public heating in Hebei comes from coal, whereas Beijing and Tianjin have gradually replaced coal heating with natural gas.[52] A 30% reduction in industrial sector emissions has an impact on winter PM2.5 concentrations only slightly smaller than that of the domestic (mainly heating) sector. In the summer, a 30% reduction in industrial emissions has by far the largest impact on ambient air quality across all cities in Jing-Jin-Ji.

In the winter and summer, agricultural sector emissions reductions had the third largest impact on air quality, with the exception of the large cities of Beijing and Tianjin, where emissions cuts from transportation had the third

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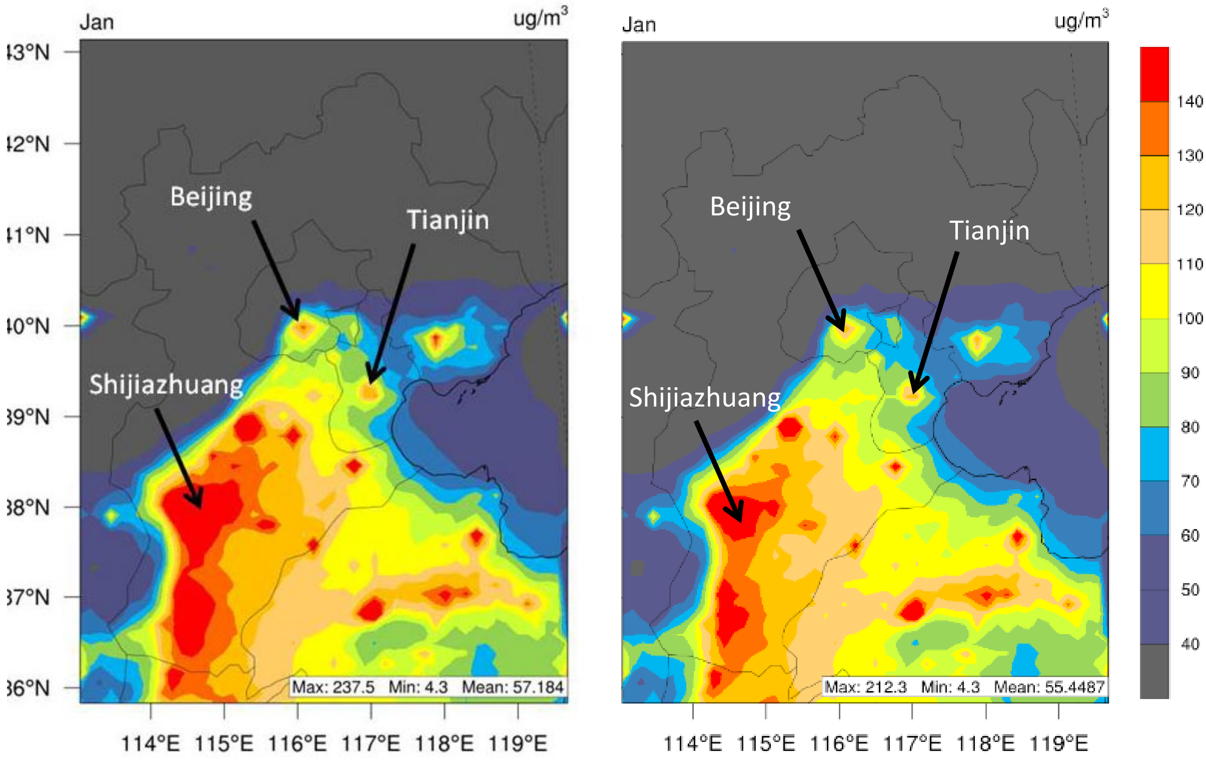
* **Industry** includes industrial processes (steel, non-ferrous metals, building materials, coking, petroleum refinery, chemical synthesis, crude/gasoline/diesel distribution, fossil fuel exploitation, black carbon production, fine chemical industry, food production, pharmaceuticals industry, and other industrial processes); industrial combustion (combustion process for providing industrial hot water or hot gas); and industrial solvent use (painting, printing, adhesive, wood protection, and degreasing). **Electric power** includes coal-fired, oil-fired, gas-fired, nuclear, and hydroelectric, wind, solar power plants, as well as biomass, and tide power. **Buildings** includes emissions from combustion process for providing domestic heating (stoves, boiler, heater, and district heating), household appliances, and electric appliances in commercial buildings; from waste water and solid waste treatment and utilization, smoking, and cooking; and solvent use (wood coating, application of pesticides, personal care, and drying cleaning). **Agriculture** includes emissions associated with farming, livestock breeding, and fertilizer use. **Transportation** includes emissions from on-road transportation (diesel, gasoline, CNG, LPG, electric, hybrid power trucks, buses, cars, and motorcycles) and off-road emissions (tractors, construction machines, railway transportations, and inland waterways)

** The Paulson Institute and Tsinghua used a 30% reduction to visually demonstrate the impact of a reasonable reduction in primary emissions across industries based on China's goals set forth in the 2013 Air Pollution Prevention and Control Action Plan.

largest impact in the summertime. Power sector emissions reductions had the smallest impact on ambient air quality in both winter and summer. Most thermal power plants in the region have already installed advanced emissions control equipment. [53]

One caveat here is to note that this analysis depends upon the accuracy of the emissions inventory used. For example, the low sensitivity of this model's result to transport emissions depends on model assumptions concerning use of vehicle emissions control technologies, and therefore may underestimate actual emissions. [54]

IMPACT OF A 30% EMISSIONS REDUCTION FROM INDUSTRY ON JING-JIN-JI AMBIENT PM2.5 CONCENTRATIONS IN JANUARY



Using sophisticated air quality modeling software, Tsinghua University performed a sensitivity analysis of the relative improvement in air quality that would result from cutting emissions from each sector of the economy. These two maps illustrate the results of this air quality monitoring in January, historically one of the most polluted months of the year. The left-hand chart portrays the base case of ambient PM2.5 concentrations in the Jing-Jin-Ji region, showing that the dirtiest air is clustered around the major cities such as Shijiazhuang in Hebei, Beijing, and Tianjin. Reducing emissions from industry alone produces a modest but significant impact on ambient PM2.5 across the region, as shown by the slightly lighter shades of yellow-orange in the urban areas of the region shown in the right-hand chart. (These reductions are more apparent in the bar charts shown on the following pages.)

Source: Tsinghua University, 2015

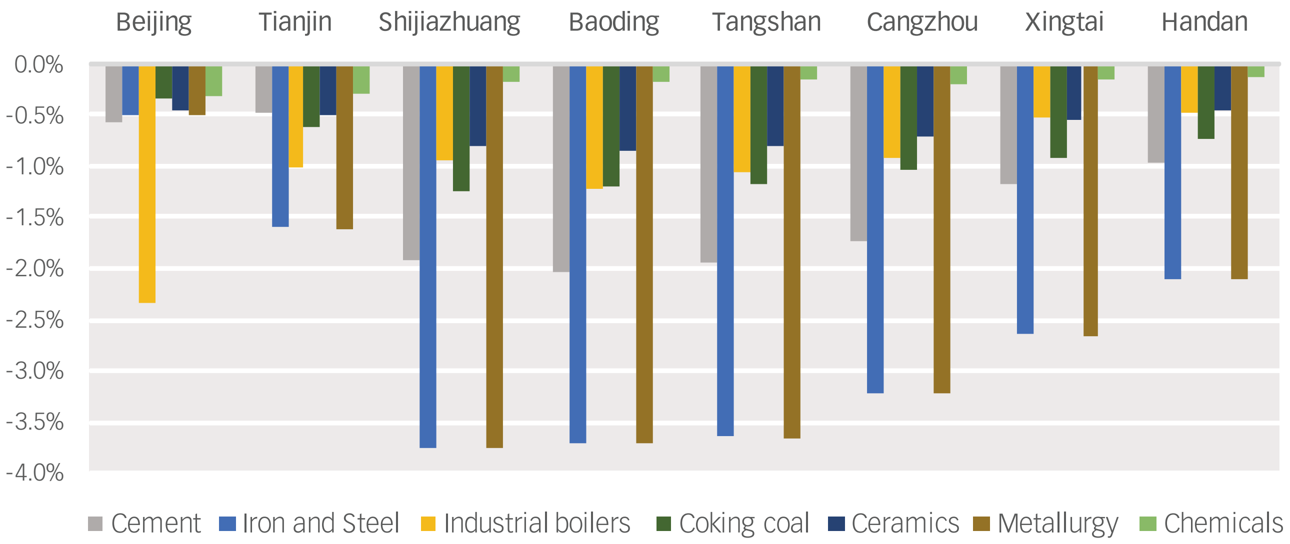
The Tsinghua University research also sheds light on the air quality impact of individual industrial sectors, specifically iron and steel, metallurgy, cement, chemicals, and glass. Based on modeling results, the two industrial sectors with the largest potential impact on Jing-Jin-Ji urban air quality are iron and steel, followed by metallurgy. For the heavily industrial cities such as Shijiazhuang, Baoding and Tangshan, cutting iron and steel production emissions by 30% would result in a 3.5% improvement in air quality (all pollutants considered), far larger than the impact of other industrial sectors.

IMPACT OF A 30% CUT IN PRIMARY EMISSIONS ON PM2.5 CONCENTRATION IN JING-JIN-JI CITIES

A sensitivity analysis performed by Tsinghua University evaluated the impact on regional air quality of a 30% cut in emissions from individual sectors—namely industry, domestic (including heating), agriculture, transport and power. The sensitivity analysis employed regional air quality modeling software to evaluate the impact of emissions cuts by sector on air quality in eight cities of the region. In January, cutting emissions from industry and the domestic sector (mainly public heating) resulted in the largest improvement in air quality (as measured by local ambient PM2.5 concentrations in this graph). In July, cutting emissions from industry resulted in the largest improvement in air quality.

Source: Tsinghua University, 2015

IMPACT OF A 30% CUT IN INDUSTRY SECTOR EMISSIONS ON PM2.5 IN JIN-JIN-JI CITIES



A sensitivity analysis performed by Tsinghua University shows that among major industries in the Jing-Jin-Ji region, cutting emissions from the region's iron and steel sector and the metallurgy sector would produce the largest improvement in ambient air quality in various cities of the region.

Source: Tsinghua University, 2015

These modeling results provide helpful insights for national-level, regional, and municipal-level policymakers in the Jing-Jin-Ji region. **First, the results underscore the magnitude of potential air quality improvement from cuts in industrial and public heating emissions.** While the general public has the tendency to focus on the most visible source of emissions—namely, passenger cars in the traffic-choked megacities of Beijing and Tianjin—Tsinghua's modeling suggests that cuts to transportation emissions would have a far smaller effect than reducing industrial sector emissions. Adjusting the fuel sources of public heating, such as through conversion of coal-based heating to natural gas or electric heating, could also have a meaningful impact on lowering emissions in the region. While these results do not address the cost-effectiveness of different measures by sector, which is a major policy consideration, we note that other studies have found ample room for cost-effective emissions reductions measures in the industrial sector. [55] Potential reductions from various sources should be considered together with the costs of achieving them, with an eye to identifying cost-effective solutions.

Second, based on these results, policymakers should focus on identifying cost-effective opportunities for emissions reductions in the iron and steel and metallurgical sectors, since these would likely produce the largest impact on ambient PM2.5 concentration in Jing-Jin-Ji's most industrial cities such as Shijiazhuang.

More broadly, **these results highlight the importance of a long-term economic transition away from high-emissions heavy industry in the Jing-Jin-Ji region.** Decades ago, when the Jing-Jin-Ji region began to industrialize, it made sense from an economic and planning perspective for heavy industry to cluster around the region's largest cities, rail lines and ports. But given the health and economic implications of air pollution in Northern China, and the growing population of the Jing-Jin-Ji region, it now makes sense for policymakers to focus on developing cleaner industries and services in the region while transitioning away from industries geared towards providing the raw materials—steel, cement, glass—that originally powered the nation's urbanization strategy.

3.3 Within each industry, there are major opportunities for emissions reductions and energy efficiency improvements

While some may assume that the only way to reduce industrial emissions is to reduce economic growth, emissions reductions are in fact highly compatible with improved economic performance. Efficiency gains in the industrial sector not only reduce emissions (and the associated macroeconomic costs of pollution); they save companies money by reducing fuel expenditures. Efficiency spending on equipment upgrades can also reduce maintenance activities and extend the useful life of a facility. China's economy is overly dependent on heavy industry and capital investment, so a transition toward services and consumer products has the potential to reduce emissions while diversifying the economy and boosting long-term growth.

> While some may assume that the only way to reduce industrial emissions is to reduce economic growth, in fact emissions reductions are highly compatible with improved economic performance.

As the preceding analysis shows, the steel sector is a logical priority for energy efficiency and emissions policies. China has been the world's largest steel producer for nearly two decades, and as of 2010, steel production was responsible for 27% of primary energy use across the nation's entire manufacturing sector. [56]

In collaboration with China's Energy Research Institute (ERI) and National Center for Climate Change Strategy and International Cooperation (NCSC), the U.S. firm Energy Innovation modeled how efficiency improvements in China's iron and steel sector would affect national emissions of pollutants such as PM2.5 and CO_2.* Their analysis considered the impact of dozens of policy and regulatory scenarios on emissions, including improvements in steelmaking equipment efficiency, fuel-switching away from coal, early retirements of old or inefficient plants, waste-heat recovery in certain plants, and remediation of system efficiency bottlenecks at certain facilities.

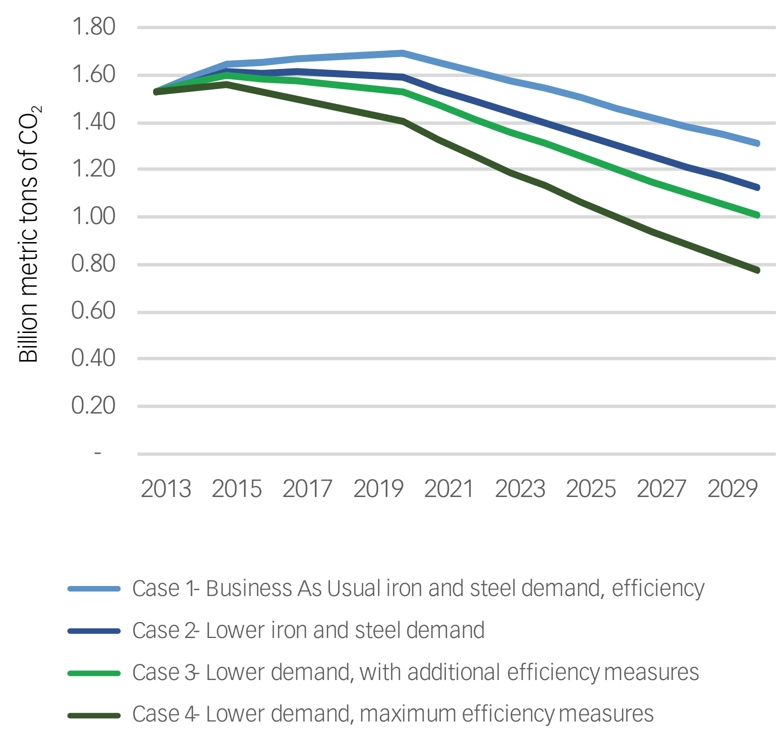
Energy Innovation's analysis also considered the impact of reduced overall demand for basic industrial products on steel sector emissions, reflective of China's stated goal of transitioning away from investment-led growth towards a consumer-led economy.

* For the complete model results across sectors, please see http://china.energypolicy.solutions/

From among these many simulations, we highlight four specific scenarios here: a business-as-usual case (case 1), a case with lower iron and steel end-use demand (case 2), and two cases that show the effect of medium (case 3) and high (case 4) efficiency improvements in industrial equipment versus case 2.

Compared to the business-as-usual (BAU) case, which already includes some efficiency improvements and reduced future demand for iron and steel products, efficiency improvements in the iron and steel sector have a profound impact on both PM2.5 and CO_2 emissions reductions. For CO_2, the most advanced efficiency measures, when combined with lower iron and steel demand, reduce 2030 emissions by 41% compared to the BAU case. Most of these reductions—over two-thirds—came from energy efficiency measures.

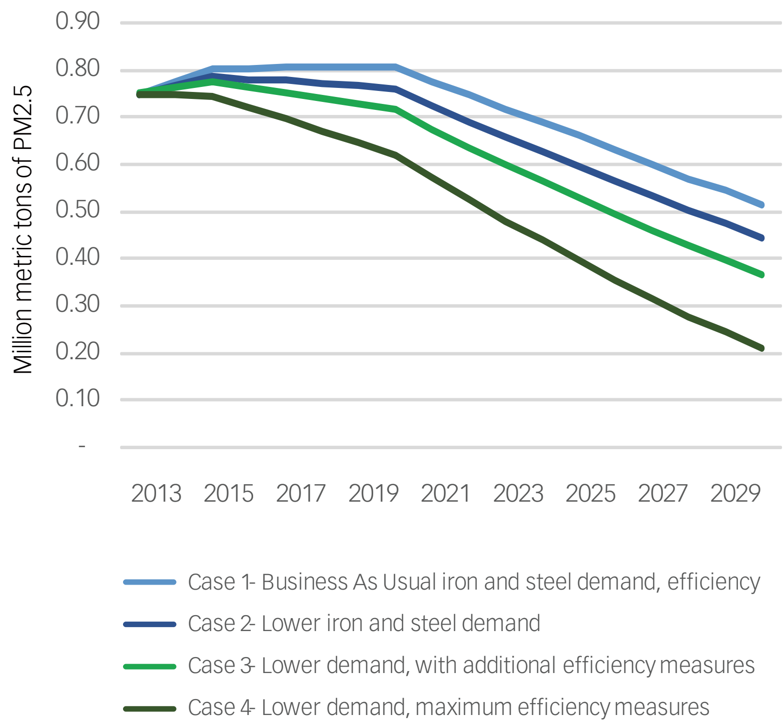
CO_2 EMISSIONS REDUCTION POTENTAL OF IRON AND STEEL SECTOR THROUGH 2030



As of 2013, the iron and steel sector emitted over 1.5 billion metric tons of CO_2 annually. Government economic plans suggest a gradual leveling off and then decline in China's iron and steel demand, which will itself cut the sector's PM2.5 emissions to around 1.35 billion metric tons annually. Additional production cuts could reduce this to around 1.15 billion metric tons. Energy efficiency measures that the government believes are reasonably feasible and economic could cut the sector's emissions by a further 400 million metric tons. The overall conclusion is that efficiency improvements can have a substantial impact on the sector's emissions.

Source: Energy Innovation, National Center for Climate Change Strategy and International Cooperation, and Energy Research Institute, 2015

PM2.5 EMISSIONS REDUCTION POTENTIAL OF IRON AND STEEL SECTOR THROUGH 2030



As of 2013, the iron and steel sector emitted over 750,000 metric tons of PM2.5 annually. Government economic plans suggest a gradual leveling off and then decline in China's iron and steel demand, which will itself cut the sector's PM2.5 emissions to around 500,000 tons annually. Additional production cuts could reduce emissions to around 430,000 tons. Energy efficiency measures that the government believes are reasonably feasible and economic could cut the sector's emissions by a further 230,000 tons. The overall conclusion is that efficiency improvements can have a very substantial impact on the sector's emissions.

Source: Energy Innovation, National Center for Climate Change Strategy and International Cooperation, and Energy Research Institute, 2015

Factoring out the impact of reduced demand for iron and steel, efficiency gains and fuel-switching in the steel sector result in a 31% reduction in CO_2 emissions and a 52% reduction in PM2.5 emissions.

For PM2.5, the effect is even more significant, with efficiency gains and demand reduction combining to produce a 59% reduction in steel sector emissions. Factoring out the impact of reduced demand for iron and steel, efficiency gains and fuel-switching in the steel sector result in a 31% reduction in CO_2 emissions and a 52% reduction in PM2.5 emissions, as compared to the BAU case. In terms of China's total annual emissions of CO_2 and PM2.5, these represent cuts of 3% and 9%, respectively, versus the BAU case—just from the steel sector alone.

Steel sector upgrades are poised to have a particularly beneficial impact on air quality in China's Jing-Jin-Ji region given the region's heavy dependence on this sector. Efficiency improvements from energy-saving technologies and optimization in steel manufacturing, in many cases mandated by

China has become a global leader in renewable energy development.

government-instituted programs, have already resulted in a reduction in energy consumption nationwide since the 1990s. [57] While energy efficiency in the iron and steel sector increased by 60% between 1994 and 2003, based on a 2012 analysis of 50 enterprises in the steel industry, there are still huge opportunities for efficiency upgrades. [58] Policies that promote additional technology upgrades and energy efficiency improvements—such as waste heat recovery, greater automation of production and monitoring, and preventive maintenance—are just a few ways that China can improve processes and reduce carbon emissions from the sector. [59]

China also has the opportunity to build upon the policies and programs of the 11th and 12th Five-Year Plans—such as the NDRC's Top-1,000 and Top-10,000 Enterprises Energy Efficiency Programs—to continue improving energy efficiency in steel manufacturing. [60] Automation will play a major role in achieving these improvements. Studies predict that between 2014 and 2018, China will have invested RMB 900 billion in automation solutions across manufacturing, equivalent to a doubling of China's factory automation market within a three- to four-year time frame. [61]

3.4 New and emerging clean energy industries are driving sustainable economic growth

As demonstrated above, upgrading industrial capacity to cleaner and more automated processes is an essential part of transitioning to a clean and prosperous economy. In addition to industrial efficiency improvements, emerging industries are increasingly contributing to China's growth, leading to a virtuous cycle: Efforts to enforce environmental policies and encourage cleaner industry can reduce emissions and help diversify the local economic base, in turn encouraging more clean industries and services to move to the region. These emerging industries include both renewable energy and energy efficiency, both discussed in greater detail below. Trends in these sectors will help gradually reduce emissions and transition towards a cleaner economy that can support greater growth.

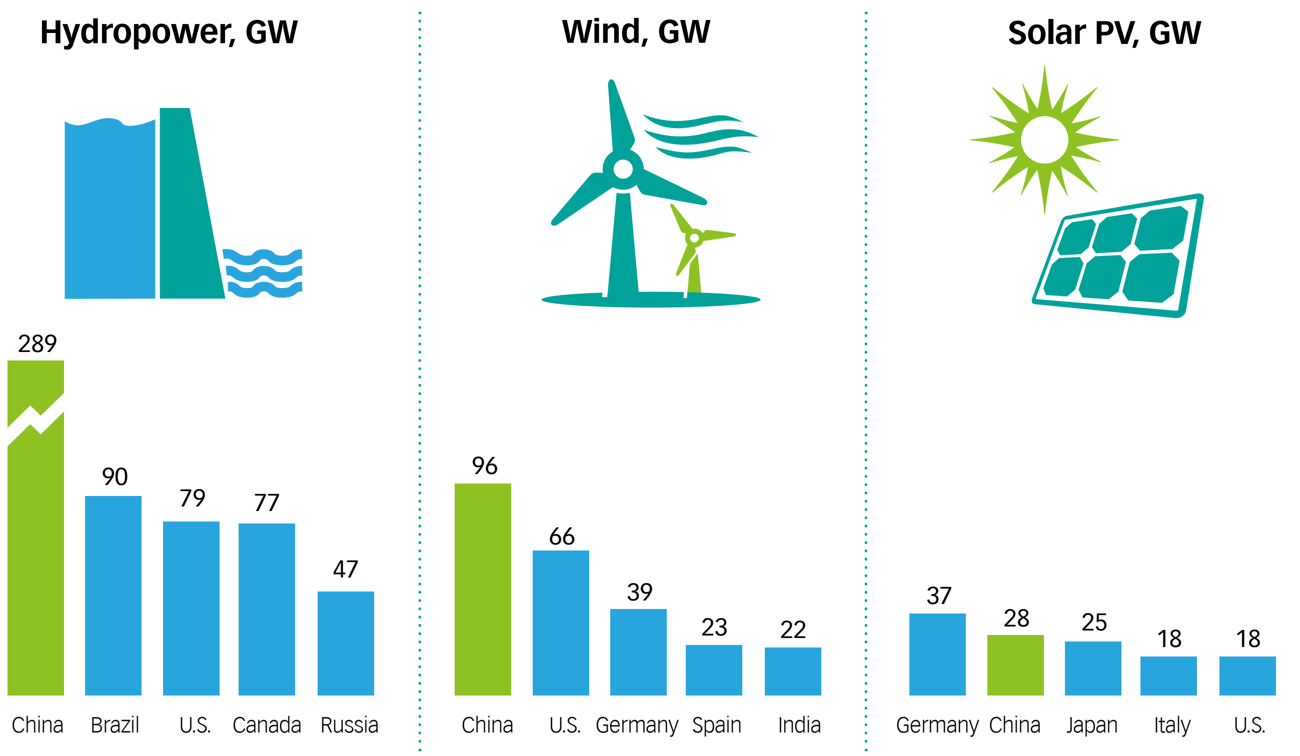
China has become a global leader in renewable energy development: renewable energy development. Through policy, projects, and infrastructure investment, the nation has made impressive strides to reduce dependence on fossil fuels and build an expansive, clean and low-carbon energy system. Numbers speak volumes. In 2014, China ranked first for total installed renewable energy capacity in the world, with the highest global installed capacities for hydroelectricity, wind, solar thermal, and geothermal. [62] For solar PV, China ranked second in 2014 after Germany. [63]

China's renewable energy policies and impressive installation rates have driven this growth. The National Energy Administration's August 2012 12th Five-Year Plan on Renewable Energy established aggressive targets for annual renewable energy utilization, requiring China's installed capacity for hydro, grid-connected wind, and solar to reach 290 GW, 100 GW, and 21 GW respectively by 2015. [64] NDRC's November 2014 National Plan on Climate Change (2014-2020) set even more aggressive goals, raising installed capacity targets for wind and solar power to 200 GW and 100 GW by 2020. [65]

To achieve these targets, China is investing along the entire renewable energy value chain, creating jobs in R&D, manufacturing, operation, and maintenance. This growth, and the resulting opportunities for investors, have been recognized by international markets: for example, Ernst & Young's (EY) September 2014 Renewable Energy Country Attractiveness Index ranked China the number one country for renewable energy investment and deployment attractiveness based on a range of factors including natural resource availability, financing, grid connectivity, and political support. [66] Similarly, analysis firm Clean Edge noted in 2014 that China has jumped into first place among countries installing solar and wind capacity, and remains a leading investor across all clean energy technologies. [67]

In addition to policy support from government, increasingly low costs associated with renewable energy development also support China's clean energy development and corresponding green job growth. China has been a major contributor to falling solar prices, from both a domestic and global perspective, due to the sheer scale of its renewable energy manufacturing scale-up and deployment. [68]

TOTAL INSTALLED CAPACITY IN GW FOR RENEWABLE POWER, BY COUNTRY, AS OF YEAR-END 2014



As of 2014, China had more hydropower and wind capacity than any other country and ranked second in solar PV capacity.

Source: Renewables 2015 Global Status Report; China wind capacity adjusted to show only year-end grid-connected capacity.

The International Renewable Energy Agency predicts that the portion of renewable energy in global energy utilization could double by 2030, creating more than 16 million direct and indirect jobs.

These industry shifts do not come without a cost. Automation and closure of outdated capacity will lead to some job losses for industrial workers in Hebei and elsewhere in China. While newer industry may never supplant all these jobs, clean energy industries do have ample job-creation potential. According to a 2010 study by the Institute for Urban and Environmental Studies (IUE) and the China Academy of Social Sciences (CASS), green growth policies such as investment in renewable energy technology and energy efficiency technologies would directly or indirectly create 30 million jobs.* While closure of small coal plants would cost 800,000 jobs, the CASS study estimated that by 2020 over 1 million jobs would be created in emissions control and higher-efficiency coal combustion plants and suppliers, and over 4 million jobs in renewable energy. [69] Similarly, a 2015 Natural Resources Defense Council study of China's policies to cap coal consumption suggested that such policies would result in substantial net job creation. [70]

International experience supports these predictions, and indicates that renewable energy development and energy efficiency investments have consistently had a positive impact on employment and overall economic growth. This is because as the cost of renewable energy declines and clean energy becomes more competitive, demand for clean and efficient energy products increases, with a corresponding increase in job opportunities across installation, operations, and maintenance. [71] The International Renewable Energy Agency predicts that the portion of renewable energy in global energy utilization could double by 2030, creating more than 16 million direct and indirect jobs. [72] While these employment studies are not definitive, they suggest a positive relationship between economic transition and job growth, and they also demonstrate the potential benefits of a transition toward emerging clean energy industry development. However, the corresponding decline in heavy industry jobs also points to the potential need for transition assistance and job training support in those communities with the highest job losses.

In addition to accelerating job growth, clean energy development will support China's economic transition. The Rocky Mountain Institute's (RMI) "Reinventing Fire: China" study illustrates the role of renewable energy and energy efficiency

IMPACT OF LOW-CARBON DEVELOPMENT ON CHINA'S POWER SECTOR JOBS (2005-2020)

OVERALL: 9 MILLION DIRECT AND INDIRECT JOBS BY 2020			
	Direct Employment	Indirect Employment	Total
Thermal Power	251,000	29,000	279,000
Wind Power	848,000	2,309,000	3,157,000
Solar Power	50,000	1,237,000	1,287,000

Source: China Academy of Social Sciences

Jobs in wind and solar are growing the fastest as China expands renewable energy to satisfy energy needs. Jobs created in the wind sector will likely be twice that of those created in solar.

* Gross job additions.

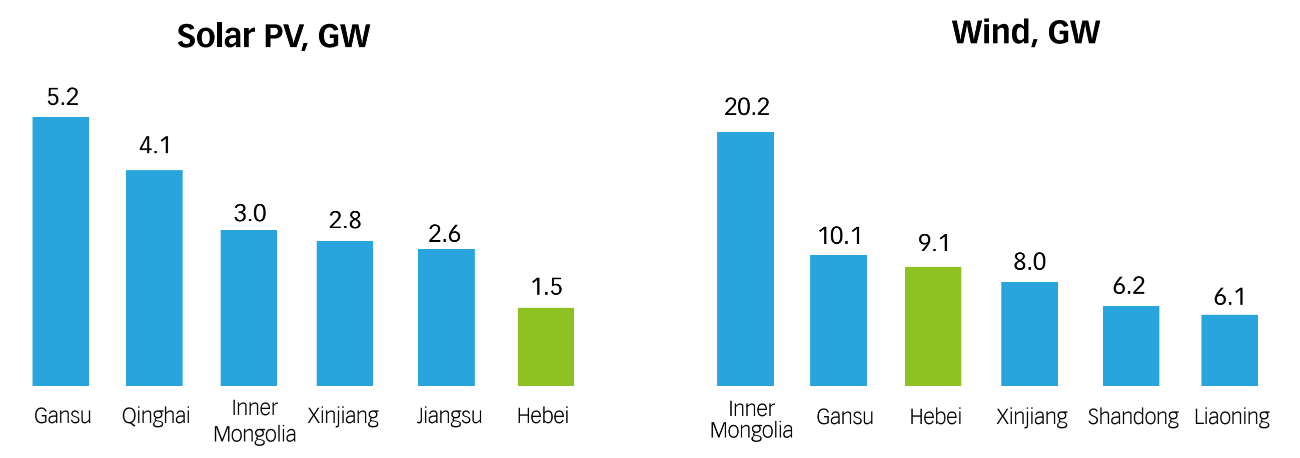
in decoupling growth from energy-intensive processes.[73] According to the study, China can achieve independence from fossil fuels while employing efficiencies and cleaner fuels across the industry, buildings, transportation and electricity sectors—in part through such measures as ultra-light vehicle materials, integrative design of industrial and residential facilities and buildings, and higher penetration of wind and solar backed by small amount of energy storage.[74]

While new job creation does not necessarily benefit the workers who may be at risk from job losses in older sectors, the employment effect is likely positive at the regional and national level. At the local level, special retraining or relocation policies will likely be needed to address short-term dislocations. It is also important to note that many job losses in high-emissions heavy industries are related to automation and closure of outdated capacity, with environmental policies as a secondary or tertiary factor. Thus, the Jing-Jin-Ji region does not face a choice between "jobs and the environment," but rather a longer-term transition involving upgrading and diversifying the regional economy.

Increased renewable energy production and deployment has the potential to play an important role in transitioning the Jing-Jin-Ji region into a low-carbon, advanced economic hub. While China is a world leader in manufacturing and deploying renewable energy, growth has been slower in Jing-Jin-Ji. Nevertheless, several cities are beginning to recognize the value of clean energy and are diversifying their economies in this direction.

Given that Hebei has high local demand, excellent wind and solar resources, and good transmission connection to neighboring regions, the province can benefit both economically and environmentally from greater investment in wind and solar. Hebei already has substantial renewable energy capacity, but renewable energy accounts for a small share of the province's consumption. The region's present energy picture is one of heavy reliance on fossil fuels. Coal-

HEBEI RENEWABLE ENERGY INSTALLED CAPACITY IN RELATION TO OTHER PROVINCES (AS OF 2014 YEAR END)



Hebei ranks sixth in terms of installed solar PV capacity and third in terms of wind capacity.

Source: Paulson Institute, based on NEA data, 2015 fired power provides over 90% of the province's energy, and coal is virtually the sole fuel for Hebei's coal, glass and metallurgy industries. Renewable energy, [75] on the other hand, represents a very small portion of Hebei's energy mix. Most of the province's wind capacity is located in the wind-rich regions of Chengde and Zhangjiakou. As of September 2015, Hebei has 9 GW of wind installed, out of a national total of over 105 GW as of mid-2015. [76] Similarly, while Hebei's solar potential is comparable to that of Central Spain, [77] and the province benefits from relatively high national feed-in tariffs for solar energy, most of China's large solar plants are elsewhere in relatively remote and sparsely populated provinces such as Xinjiang, Qinghai and Gansu. [78] While Hebei ranks sixth in terms of provincial installed solar capacity as of Spring 2015, Hebei accounted for just 4.6% of all solar PV installed in China. [79] For 2015, China's National Energy Administration set a target for Hebei to achieve 1 GW of new solar installations, which if achieved would make Hebei one of the most important provincial markets for solar. [80]

As the Jing-Jin-Ji region boosts investment in clean energy to achieve its air quality goals, distributed solar development is one example of how the energy system is beginning to transform from a centralized model dependent upon coal plants to a distributed model based on user-sited energy. For example, distributed PV can help the Jing-Jin-Ji region meet flexibility demands and improve grid stability.

Despite central government policies to promote distributed energy (including rooftop solar), China's largest provinces are lagging behind in deployment—even though China's urbanized coastal provinces have relatively rich sunlight resources

Handan Textile Rooftop Solar Project

Location: Handan, Hebei

Construction date: 2014-2015

Output (capacity): 1.5 MW

Technology employed: Solar photovoltaic (PV) panels, inverters and related power controllers

Economics: Estimated 15-20% return on investment to date

Handan textile invested in rooftop solar to save money and support local employment. The solar panels (pictured here) produce approximately 7-8% of the facility's electricity demand. On a sunny summer afternoon, solar may provide up to one third of the 280-employee yarn and fabric-making plant's electricity.

compared to other leading solar countries such as Germany or the U.K. Analysts have cited a number of barriers to explain the slow expansion of distributed solar, including a slow approval process, difficulty processing subsidies and payments for solar power injected into the grid, and even air pollution itself.[81]

As the economics of distributed solar improve, these barriers are gradually being overcome. In Handan, Hebei Province, a city known for its coal and steel industry and heavy air pollution, Handan Textile decided to take the leap and invest in rooftop solar. Unlike many examples of distributed solar, this was not a government-led demonstration, but rather a business decision on the part of the company based on considerations of real cash returns. Government policies were a factor in the investment decision, including the RMB 0.42/kWh distributed solar subsidy from the central government. Following a feasibility report and on-site testing of different solar PV panels manufactured in Hebei and Zhejiang, the company decided to proceed with a full-scale installation in 2014. "This was a company-led initiative," a member of the company's senior management told our researchers.[82]

The results are promising: Whereas the company's independent feasibility report suggested the project would earn cash returns of 16%, the firm's management believes so far they have netted over 20%, on the basis of higher-than-expected solar generation and frequent maintenance to remove dust.

The Handan Textile case is an example of how government policies—when combined with technology diffusion through learning-by-doing, knowledge spillovers, and effective marketing—can support the growth of clean industry.

The built environment is a sector where China is seeing some of the greatest growth in technology development and adoption, innovation, and job gains.

China Academy of Building Research Near-Zero Energy Building

Location: Beijing

Construction date: 2014

Floor area: 4,025 square meters

Technologies employed: Solar energy (both photovoltaic and solar thermal for heating and cooling), solatubes and day-lighting, triple-pane low-E glass, LED lighting, radiant heating and cooling, ground-source heat pumps.

Economics: At RMB 4,000/m^2, the building is 15% more expensive versus conventional alternatives, and has an economic payback of 5-8 years.

The China Academy of Building Research's Near-Zero Energy Building in Beijing (pictured here) has an energy use profile that is 75% lower than a typical Beijing office building employing conventional practices.

To be sure, several barriers to distributed solar in Hebei remain. At the moment, distributed solar PV costs are still too high to compete without government subsidies, unlike in other world regions where solar has reached parity with end-user power prices. This is partly due to relatively low electricity prices in China, especially in some areas where industrial energy use may be partly subsidized to attract industry.

3.4.1 China is gaining experience and knowhow in green building technology

By working collaboratively with a large number of stakeholders, CABR is enabling others within the supply chain to learn about cost-effective energy efficient materials and equipment.

The building sector consumes a third of China's primary energy (though this figure includes industrial buildings), and total energy consumption—and therefore resulting carbon emissions—is rising as the nation's building floor area expands at the rate of 2 billion square meters a year. [83] Building energy efficiency has become one of China's highest priorities for energy savings and emissions reductions. The built environment is a sector where China is seeing some of the greatest growth in technology development and adoption, innovation, and job gains.

Energy efficient technologies, materials, and integrated design can all reduce the energy consumption of buildings. Nevertheless, until building developers see that energy efficiency has real monetary value, emissions from the built environment will likely continue to rise. Today, developers, investors, and owners often argue they have no real incentive to prioritize low-energy, sustainable buildings. Furthermore, barriers such as challenges in diffusing technology knowhow and difficulty in demonstrating user appeal of new technologies hinder wide scale implementation of energy efficiency practices.

The China Academy of Building Research (CABR)'s Near-Zero Energy Building in Beijing illustrates how government demonstration projects can help address these barriers in two respects: First, the building demonstrates a large number of advanced energy-saving technologies and materials, specifically selected for their cost-effectiveness and applicability to China, particularly for the climate conditions and usage patterns of a low-rise Beijing office building. Second, by working collaboratively with a large number of stakeholders, including developers, technology suppliers, and international partners such as the U.S.-China Clean Energy Research Council, CABR is enabling others within the supply chain to learn about cost-effective energy efficient materials and equipment. This includes technology transfer from international technology suppliers and research institutions as well as providing educational and practical learning-by-doing through working with Chinese suppliers, designers, and developers.

In total, the CABR building employs 28 emerging or already commercial energy efficient building technologies. The building's energy use profile over its first full year of operations was 25 kWh per square meter, 75% lower than a typical Beijing office building employing conventional practices. These savings are closely linked to the building's integrated design, which is based upon three central principles: prioritizing passive building elements, optimizing active energy-use elements, and utilizing cost-effective technologies and practices. Design elements are meant to achieve several targets: eliminating the use of public heating in the winter, cutting lighting energy use by 75% as compared to a similar, typical building in Beijing, and reducing summer air conditioning energy use by 50%.

Because the building's purpose is to demonstrate technologies that are ready to be scaled up in China, cost-effectiveness was a major criterion. The design target was to achieve a total building cost per unit of floor area no greater than 15% higher than that of conventional building practices. CABR termed its technology selection and design process as "bold but effective": the completed building is estimated to have cost RMB 4,000/square meter, with energy and operational cost savings that will enable a payback period of 5-8 years for premium equipment and materials.

The need for energy efficient window products in advanced, energy efficient buildings like CABR's is creating a demand pull for upgrades in the glass manufacturing sector, including in Hebei. For example, the windows at CABR are triple-paned, low-e insulated glass units, manufactured in Hebei at Orient Sundar Window Group in Baoding. Sundar has grown from a small firm of just a dozen employees producing hand-made glass products to a glass company with over 3,000 employees specialized in energy-efficient glass products. Sundar now supplies energy efficient window and door products to several of China's largest property development firms, such as Vanke and Poly Group, as well as to several passive house projects in Europe and the U.S.

Solar thermal heating-and-cooling is an example of a nascent technology with scale-up potential—with real implications for employment in places like Hebei.

While solar hot water heating is already widely commercialized for buildings in China, and rooftop solar photovoltaic panels are commercial and potentially at the cusp of widespread deployment, few building market players are familiar with solar thermal heating-and-cooling. The CABR Near-Zero Energy Building takes advantage of this technology by employing a set of low-concentrating panels mounted in a near-flat orientation on the building's rooftop, which generates approximately 13,000 kWh of thermal energy per summer for heating or cooling water. The building also employs radiant cooling units mounted in the ceilings, and radiant heating located beneath the floors for winter. Advanced equipment enables building managers to monitor occupancy, ventilation rates, temperature set points, and window openings to maximize energy savings while ensuring thermal comfort and proper humidity levels.

Solar thermal heating-and-cooling is an example of a nascent technology with scale-up potential—with real implications for employment in places like Hebei. The supplier of CABR's solar thermal heating-and-cooling panels, Linuo Ritter International, is located in Shandong Province where it currently employs around 1,000 workers, including hundreds of employees in marketing, manufacturing and supply chain management.

Overall, building energy efficiency is a way for building owners and tenants to save money, with ripple effects through the entire building products and services supply chain. As developers and suppliers gain knowhow and experience successfully deploying these technologies, the result is not only lower energy consumption per unit of economic output, but also technology innovation that can lead to exports outside the region, driving competitiveness of buildings-sector materials and services for sustainable economic growth.

4. LESSONS FOR JING-JIN-JI FROM U.S. ECONOMIC TRANSITION CASES

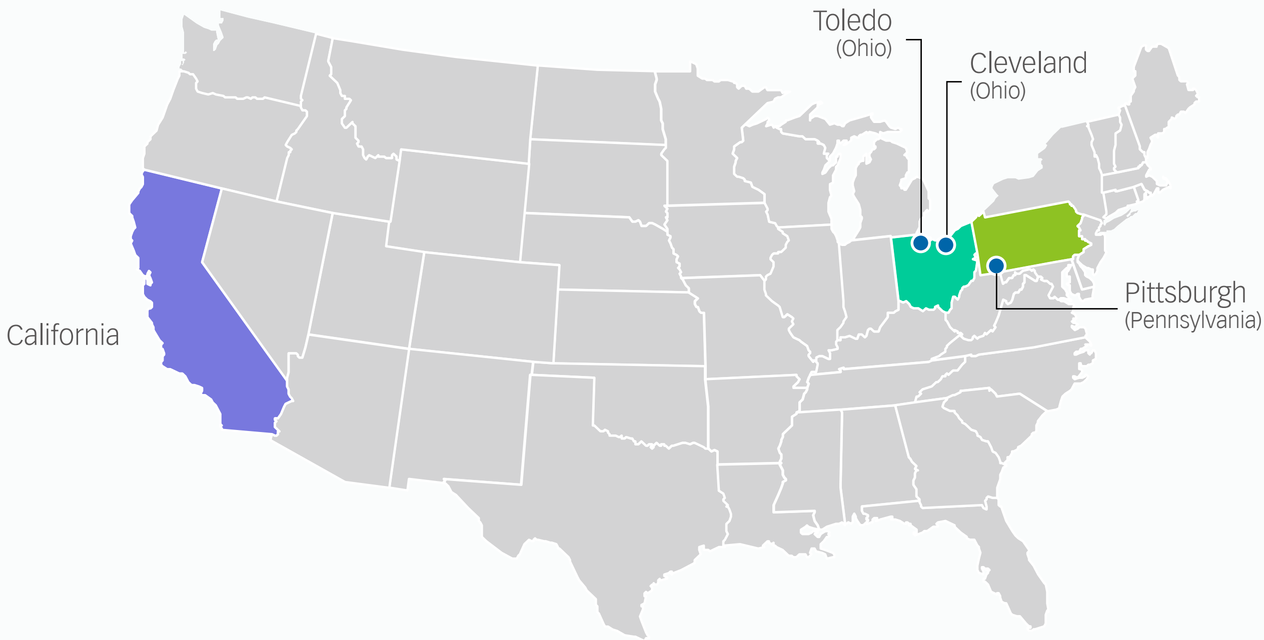
China's situation is unique, as are the challenges the country faces, but the country's leaders and scholars also recognize that China can benefit from studying examples of regions and cities that have reduced emissions and undergone transitions away from manufacturing and fixed-asset investment. A select number of U.S. regions and cities—Pittsburgh, Pennsylvania; Toledo and Cleveland, Ohio; and the state of California—provide potential lessons and examples for leaders of cities in the Jing-Jin-Ji region. In some cases, like California, the lessons are largely positive: cities can clean the environment while continuing to grow. In other cases, like the U.S. Rust Belt—an area of the U.S. Northeast that experienced job losses and de-industrialization from the 1950s to the 1980s—there are also lessons on what to avoid.

The case of California illustrates how forward-leaning environmental and energy policies fostered the growth of clean energy industries, innovation and jobs.

- The U.S. Rust Belt city of **Pittsburgh** fell into decline due to the collapse of the steel industry in the 1970s. Today, Pittsburgh is often cited as a success case of economic recovery, showing how a vibrant city with strong local institutions can reinvent itself as a hub for services and innovation. Pittsburgh's economic recovery over the past two decades is intimately tied to the city's educational institutions—and particularly with targeted R&D spending in computer science and health care—as well as to supportive, collaborative policies from the local government and philanthropic institutions. The Pittsburgh case illustrates the importance of economic diversity, tech cluster strategies and willingness to adjust to the departure of former anchor industries.
- The state of **Ohio**, also located in the U.S. Rust Belt, shows how industry upgrading and policies around renewable energy can spur investment and job creation in clean energy. In particular, Ohio's expertise in glass manufacturing played a critical role in developing a local solar cluster. As in the case of Pittsburgh, the state's educational institutions played an anchoring role. While the U.S. Midwest's manufacturing recovery will never replace all the jobs lost due to de-industrialization, promoting clean energy can still be good for growth.
- The case of **California** illustrates how forward-leaning environmental and energy policies fostered the growth of clean energy industries, innovation and jobs. California's case also highlights the enormous potential of the private sector to invest in clean energy technology, under the right conditions. In California, those conditions included not only environmental policy, but a diverse industry structure as well as resources for job training and research and development. Above all, the California case shows how the state benefitted from taking the lead on environmental policy, and not waiting for other places to demonstrate feasibility first.*

* The Paulson Institute, which is headquartered in Chicago, has links to leaders and experts throughout the U.S., including in the regions described in this report. In preparing this paper, we drew on insights from a number of experts. Additional interviews and findings are available on the website of this report at bit.ly/ChinasNextOpportunity.

Economic Transition Case Studies from the U.S.



State of California
Population: 39 million (versus 20 million in 1970)
Population state rank: 1st
GDP: US$ 2.2 trillion (13% of U.S.)
GDP per capita: US$ 39,000
Key insights for Jing-Jin-Ji

- Economic and environmental prosperity can go together
- Integrated energy and environmental policy important
- Policy leadership and mandates can lead to innovation

Pittsburgh metro area
Population: 2.4 million (versus 2.8 million in 1970)
Population metro rank: 22nd
GDP: US$ 113 billion
GDP per capita: US$ 47,000
Key insights for Jing-Jin-Ji

- R&D spending decisions at top-ranked universities can catalyze economic transitions
- Public-private collaboration among a small cohort of individuals can help coordinate creation of new industries

Cleveland metro area
Population: 2.1 million (versus 2.3 million in 1970)
Population metro rank: 29th
GDP: US$ 134 billion
GDP per capita: US$ 26,000
Key insights for Jing-Jin-Ji

- Educational institutions can play a central role in transformation, fostering clusters of industry and human capital
- Key is for institutions to act as neutral "host" for companies and entrepreneurs

Toledo metro area
Population: 650,000 (versus 644,000 in 1970)
Population metro rank: 81st
GDP: US$ 24 billion
GDP per capita: US$ 37,000
Key insights for Jing-Jin-Ji

- Existing industrial expertise can help catalyze more advanced, cleaner industry
- Top-ranked educational institutions can play a role in both training and innovation to power new local cleantech industries

4.1 Pittsburgh: Targeted R&D spending and public-private collaboration

Just as Hebei is known throughout the world as a center for steel manufacturing today, Pittsburgh, Pennsylvania was a global steel powerhouse just half a century ago. The city stands at the intersection of several smaller rivers that flow into the major Mississippi and Ohio Rivers, as well as the Great Lakes. Pittsburgh is separated from the East Coast and Atlantic Ocean by the Appalachian mountain range but is open to the west. In the days when rivers were the main transportation corridors for goods, this locational advantage meant that Pittsburgh was perfectly situated during the 19th and early 20th centuries to become an industrial and manufacturing hub for the central and western U.S. [84] Along with industrialization came pollution: one 1800s writer called the city "hell with the lid off." [85]

Pittsburgh's rise to industrial strength was bolstered in the early 20th century with the discovery of a coal seam running through the region, which provided inexpensive fuel for its industrial processes. The corresponding growth of the railroad industry dramatically increased the U.S. market for steel, and Pittsburgh became the steel capital of the country, producing more than 60% of the nation's steel by 1910. [86] Other industries followed—especially heavy industries also dependent on coal, but including consumer companies like the Heinz Corporation—and by 1970 the city was the third-largest corporate headquarter city in the nation. [87]

As with other Rust Belt cities, however, Pittsburgh's fortunes started to decline in the latter half of the 20th century, as global competition brought steel prices down. The environmental impact of burning coal to produce steel also helped to turn the American public against the steel industry. Pittsburgh is famous for

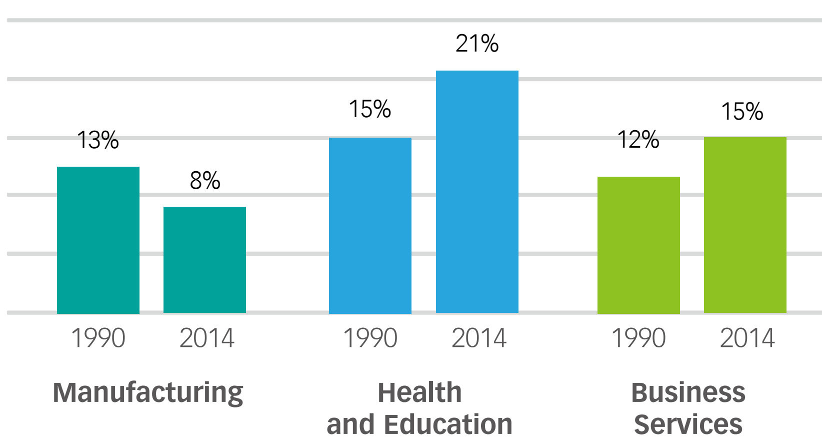
Pittsburgh Case Findings:

Problems: High unemployment due to severe downturn in steel manufacturing in the 1970s. Severe air and water pollution.

Solutions: Focused R&D spending at the city's major research universities helped create new industrial clusters in computer science, robotics and health care. Public-private collaboration helped city leaders strategically promote new industrial clusters. Legislation at the state and federal level pushed the region to clean up its air.

Results: Service and knowledge-economy industries have made major contributions to reducing Pittsburgh's unemployment and attracting new industries. Cleaner air has contributed to the city's success in changing its image and attracting companies.

CHANGES IN EMPLOYMENT SHARE BY SECTOR IN PITTSBURGH (1990-2014)



While jobs in manufacturing declined, Pittsburgh saw a growth in health and education, and business services jobs.

Source: U.S. Bureau of Labor Services and St. Louis Federal Reserve, 2015 having such terrible air pollution in the mid-1900s that streetlights had to be turned on during the day so that citizens could see through the industrial fog. [88] In 1948, in the small town of Donora on Pittsburgh's outskirts, a particularly thick smog incident killed 20 people and sickened half the town's residents, ultimately leading state leaders to adopt clean air regulations. [89] These economic and environmental realities meant Pittsburgh had to turn to other industries—specifically computer science, robotics and health care—for economic growth in the 21st century. [90]

Pittsburgh has done just this, turning around its economy so dramatically that it has become the model for other Rust Belt cities and for industrial cities around the world. Between 1990 and 2013, the greater Pittsburgh metropolitan area gained nearly 118,000 jobs, and its workforce is now so diversified that only 7.7% are employed in the manufacturing sector (down from 12.6% in 1990). [91] In contrast, well over one-fourth of Pittsburgh's workforce is employed in education, health, and business services—often known as the knowledge-based sector of the economy.

> *In Pittsburgh, it was the suddenness of the steel sector collapse that created the political space to enable restructuring. Pittsburgh got started earlier than Detroit or other cities because the steel sector collapsed earlier and more thoroughly, whereas in Detroit leaders lacked the political will to pivot away from their strength in auto manufacturing.*
>
> *– Jim Russell, Research Fellow, Center for Population Dynamics at Cleveland State University*

Pittsburgh has also become a leader in environmentally sustainable economic activities such as green buildings. For example, the city has been innovative in turning formerly toxic industrial sites, known as "brownfields," into building sites for new green buildings including a gold LEED-certified convention center. [92] The city has encouraged this development through policies such as a "density bonus"—a rule that allows developers of energy efficient buildings to build 20% higher than the limit that applies to conventional buildings. [93] The state of Pennsylvania also actively pursued renewable energy industries over the past several decades, building on its strong manufacturing workforce and geographic advantages to bring in Spanish global wind turbine producers Gamesa and Iberdrola. [94]

What is the key to this success? A recent report from Cleveland State University and the group CEOs for Cities, *From Metals to Minds: Economic Restructuring in the Rust Belt*, argues that Pittsburgh used its strong educational institutions to anchor its new economic development. [95] The authors use the metaphor of the "host at the party," where the universities are the host, greeting new business entrants and introducing them to others in research, development, and technology deployment as well as the education and service industries. This approach stands in contrast to a "life of the party" strategy, where a university might try to become the gatekeeper for all research and development, monitoring access to the local economy in favor of its own partner corporations. [96]

Anchoring role of educational institutions: In Pittsburgh, one "host of the party" is Carnegie Mellon University (CMU), which had an early computer science program that developed throughout the 1980s into a destination for students and business leaders hoping to learn how to do technology transfer between private industry and the government. That reputation brought world-class researchers and students, which in turn brought companies wanting to locate near that talent. [97] Today, Pittsburgh's network of businesses includes Google, Apple, Microsoft, Intel, Oracle, and Yahoo, among many others. Another "host of the party" is the University of Pittsburgh, or Pitt, which is a leader in life sciences research. With over 55,000 employees, the University of Pittsburgh Medical Center has acted as an economic anchor and seed for future growth. [98]

With these two institutions as cornerstones, in the 1980s and 1990s Pittsburgh focused on establishing itself as a high-tech biomedical cluster. Today, Pittsburgh's hospitals and medical centers together employ more people than the steel industry did at its height. [99] The result has been that Pittsburgh has seen rising incomes despite falling population—the city is now ranked 6th in per capita income among the top 51 U.S. metro areas. [100]

Public-private collaboration was a key ingredient in the city's success story. Pittsburgh's government worked with the private sector to transform urban areas into areas for new technology. Pittsburgh refurbished an old

Relics of the Past: The Carrie Furnace is a former blast furnace located near Pittsburgh. At its peak, it produced 1000 to 1250 tons of iron per day, and it now serves as a historical site open for tours.

Expert Voices: Rust Belt

To what extent would Pittsburgh's revitalization not have happened without a cleaner and more attractive environment?

Karen Clay: Pittsburgh's revitalization absolutely could not have happened without the cleanup. Even with the cleanup, Pittsburgh still has mild air quality issues because of geography, but its air quality continues to improve as coal plants shut down in favor of natural gas. Water quality continues to improve as well. And there has been substantial investment in amenities like riverside parks and biking trails.

Jim Russell: The immediate impact of sustainability and environmental quality on the economy relates to health and worker productivity. That said, the larger benefit of cleaning up the environment is that the narrative of a place changes, and that underpins economic changes. If residents or outsiders see a dirty city, they see a hopeless city. If you can change the psychology of the city so that the residents feel it is worth defending and changing, that is valuable.

What mistakes did city leaders make over the years in revitalizing Rust Belt cities?

Sabina Deitrick: I would point to the overall slowness of some of the revitalization strategies. This slowness was due to political leaders wanting to protect jobs in older industries. In Pittsburgh, top economists reported in the 1960s that the city would have to change directions, but the leadership wasn't willing to listen. Steel was the name of the game, even when it was already shrinking. The same was true in Detroit, where leaders tended to view any downturn as merely a part of the auto sector's boom and bust cycle.

Jim Russell: The biggest mistake is an abstract one, namely the idea that there is some sort of local policy that can fix things. This is hubris. City leaders often don't pay attention to the vast macroeconomic forces that are really driving what's going on in their city. Political figures and public-private partnerships often try big capital projects to stop the "brain drain"—the departure of more educated residents—spending the region's tax money on airports, convention centers, light rail, or stadiums. Instead, they should spend money on basic research, pick a technology cluster and establish targets, like Texas went after cancer research and began poaching cancer researchers from other regions. It's a winning restructuring technique.

Aaron Renn: The number one issue that I see is that urban leaders don't handle urban planning and urban issues in a strategic way. Cities like Cleveland, Toledo, Pittsburgh and Chicago are all radically different places, but the solution set that academics or leaders propose is always or often the same.

Aaron Renn
Senior Fellow, Manhattan Institute for Policy Research

Jim Russell
Research Fellow, Center for Population Dynamics at Cleveland State University

Karen Clay
Associate Professor of Economics, Carnegie Melon University

Sabina Deitrick
Associate Professor, Graduate School of Public and International Affairs at the University of Pittsburgh

Nabisco factory downtown into an incubator space for tech and health-care companies called Bakery Square. The project—a LEED certified green building—has been so successful that a second phase is now planned. [101] Because of the city's small size compared to Los Angeles or New York City, a relatively compact core of leaders from government, academia and business were able to come together several times per year to coordinate such activities, evaluate progress, and work towards consensus on what growth strategies to pursue.

Pittsburgh and many other cities of the Midwest have historically **had strong local philanthropic institutions** that contributed to economic transition. In Pittsburgh, the Carnegie Endowment has supported a network of NGOs and private companies to work with government and community leaders to set the direction of economic transition policies, as well as fund groups to retrain workers or coach startups. Civic organizations such as Pittsburgh Community Reinvestment Group (PCRG) have helped link business leaders to officials contributing to regional economic planning. [102]

Economic diversity has also been an element of Pittsburgh's transition. While the city is famous for steel, its manufacturing sector has grown more diverse—with a mixture of firms with different specialties and technologies. As a result, some firms have been able to make the transition to advanced manufacturing. Today, the city is not only a major biomedical cluster, but also the heart of a burgeoning robotics industry. RoboCorridor, a tech zone that includes the CMU Robotics Institute, encompasses a variety of educational institutions and companies. Pittsburgh is home to startups working on robots used for applications ranging from manufacturing cars to assisting sleepy drivers, hauling construction materials inside buildings to detecting bombs. [103] Finance and professional services are also major elements of the city's economy today. [104]

Brown to Green: The David L. Lawrence Convention Center in Pittsburgh, built on a former brownfield site, is the nation's first convention center to be a Gold LEED-certified building.

Pittsburgh, a city originally built around extractive and basic manufacturing industries, has managed to diversify into a much more sustainable set of knowledge-based and low-carbon industries. Chinese cities looking to move toward a more sustainable, diversified "new normal" can benefit from the Pittsburgh example in several respects. These include the role of public-private collaboration in city economic planning; the power of local philanthropic and educational institutions in attracting innovative talent; and the importance of targeting new industry clusters through directed investments in R&D. Drawing upon these strengths, Pittsburgh has been able to reinvent itself as a leader in services and innovation.

4.2 Ohio: Renewable energy investment and comprehensive job training programs were key success factors of Ohio's transition

The U.S. state of Ohio has a long history of heavy industry and manufacturing. Ohio is a key part of the "Rust Belt" of Midwestern states mostly bordering the Great Lakes, which together dominated the U.S. manufacturing industry for much of the 20th century. In the 1950s, this region of the country accounted for more than half of all domestic manufacturing jobs, and over 40% of all U.S. jobs. [105] For Ohio, these jobs were mostly in auto manufacturing, steel, and glass. [106] But the region suffered serious declines in manufacturing over the next few decades, due to several factors, including increased international and domestic competition and the general trend toward automation in the manufacturing sector. Ohio's manufacturing sector also faced pressure throughout the second half of the 20th century because of the environmental harm caused by its heavy industries: a major fire on the waters of Ohio's Cuyahoga River gained national attention and gave rise to protests that eventually led to several major pieces of U.S. environmental policy, including the Clean Water Act, the Clean Air Act, and the creation of the Environmental Protection Agency. [107]

For Ohio, the question for the 21st century has been whether to abandon its manufacturing past, or whether to build on the industrial infrastructure and assets the state developed over the past century to promote a new kind of cleaner and more sustainable economic growth. [108] This is a very similar challenge faced by some Chinese cities today, particularly in the heavily industrialized region of Hebei. While Hebei is still a major steel producer, generating over one-fourth of China's entire steel output, it faces similar pressures to those faced by Ohio in the last century: low steel prices, inefficiencies and overcapacity within the steel sector, and the pressure from policymakers and the public to improve air quality in this heavily polluted region. [109] Chinese policymakers are also taking a forward-looking approach and working to move the entire country from a manufacturing-based economy toward a "new normal" that rebalances the economy toward more diversified and sustainable growth. For these reasons, Ohio's historic shift away from heavy industry can provide important lessons for Hebei today.

In the 1950s, the U.S. Rust Belt region accounted for more than half of all domestic manufacturing jobs, and over 40% of all U.S. jobs.

Toledo: From windows to solar

Located at the western edge of Lake Erie, and sitting at the intersection of shipping and rail lines, Toledo made a name for itself in the 19th century as a hub of manufacturing. Its particular focus was glass, and the companies Owens Corning and Libbey Glass originated or moved there. The city soon diversified into automobile manufacturing as well. But when the Rust Belt began to lose manufacturing in the later 20th century, Toledo was hit hard, losing thousands of manufacturing jobs, as well as valuable expertise and knowhow. In 2010, when the Toledo Museum of Art built a US$ 30 million Glass Pavilion, it had to import specialty glass for the pavilion's curved windows from a company based in Shenzhen—no U.S. firm had the technical capability to make the glass, even though the process was originally perfected in Toledo. [110]

That said, Toledo's manufacturing infrastructure and skilled workers, combined with the University of Toledo, became the foundation for a new kind of economic growth in the 21st century: growth in solar panel manufacturing and sales. In the late 1970s and 1980s, glass industry experts in Toledo began experimenting with techniques to deposit thin-film solar materials on glass. In 1984, the company First Solar (initially called Glasstech Solar) was founded in Toledo, through a research collaboration with the University of Toledo and with the support of government grants. The company, which makes thin-film solar panels, is now headquartered in Arizona but still employs over 1,000 people at its Toledo manufacturing plant. [111] The local glass industry knowhow, combined with support from local educational institutions across Ohio, was a critical factor in First Solar's success in mastering manufacturing techniques for the challenging process of depositing the solar material cadmium-telluride on glass substrates.

Toledo Case Findings:

Problems: High unemployment due to severe downturn in auto and glass manufacturing in the 1970s.

Solutions: Focused R&D spending at the University of Toledo in a field related to the city's industrial expertise—solar PV—helped catalyze a new industry and attract firms related to the solar supply chain.

Results: While Toledo still hasn't recovered from its industrial downturn, the city now has a large number of jobs and firms in the solar industry.

First Solar is far from the only company engaged in solar research and technology in the Toledo region. Across Ohio, there are 217 solar-related companies that work across the value chain, with most of them concentrated in and around Toledo. According to the Solar Energy Industry Association, Ohio is home to 93 manufacturers, 56 manufacturing facilities, 62 contractor/installers, 14 project developers, 11 distributors and 37 other companies engaged in related solar activities including financing, engineering and legal support. [112]

One important reason for the solar job concentration in this state is Ohio's attention to worker training in solar industries: the University of Toledo now houses a School of Solar and Advanced Renewable Energy, a Center for Photovoltaics Innovation and Commercialization, and the equivalent of an MBA for physics and engineering students who want to learn to start and run solar companies. Owens Community College also offers customized training for solar specialties for both new workers as well as older workers who need retraining. [113] This continuous feeder network of skilled and trained workers who understand the solar industry across the value chain is critical to Ohio's success in transforming from a last-century glass manufacturer to a this-century solar powerhouse.

Another lesson of the Toledo experience relates to public-private collaboration aimed specifically at economic transition. When Toledo's industrial decline began, government officials and other community leaders were focused on retaining the city's largest employers. Only after it became obvious that a transition was needed did government, business and academia band together to create a new strategy. Leaders of these three groups began to meet monthly to share ideas and strategies—and to work together to target new industries like solar. [114]

> *Our biggest contribution as a University has been working with government and business leadership to help frame the thinking around what the community needs to do to diversify the economy. We are trying to answer the question, 'How can we work together to upgrade the workforce and get our leadership connected with innovative economic networks?*
>
> *– Frank Calzonetti, Professor of Geography, University of Toledo*

The future of Ohio's solar industry is somewhat uncertain, however, due to the uneven policy environment for advanced energy industries in the state. When First Solar was founded, the state was putting into place a suite of policies supportive of the renewable energy industry, including a Renewable Energy Standard that required 12.5% of electricity sold by Ohio's electric utilities to be generated from renewable energy sources by 2027 (of this 12.5%, at least 0.5% must come from solar). [115] However, the current governor put the standard on hold in 2014, and the resulting uncertainty about the future market for solar products within the state has hurt the industry. [116] The state is also considering putting energy efficiency standards on hold, which would set back another emerging clean energy industry in Ohio—combined heat and power (CHP) for industrial operations. [117]

Lastly, it is important to note that Toledo's new energy economy will likely never support the number of local manufacturing jobs that have been lost since the city's heyday: Automation and international competition mean that even when industry returns to a region like Ohio, the manufacturing job gains are relatively modest. Toledo today is a small metro area of 650,000 people—only the 6th largest in Ohio. Partly as a result of its smaller scale, Toledo's economic recovery is far less impressive than those of nearby Pittsburgh and Cleveland, which are both larger in terms of population and boast relatively more cultural, institutional and architectural amenities. These larger cities are a magnet for talent and entrepreneurship throughout the region—even globally.

Nevertheless, Toledo's story is one that can provide hope, and also lessons, for China's industrial regions. First, Toledo underscores the fact that a strong manufacturing infrastructure—including plants and machinery but also a history of skilled workers from research and development through to production—can be the basis for economic transition into newer, more advanced, and cleaner manufacturing activities. Toledo also highlights the importance of a strong and consistent policy environment that creates a market for new emerging energy products.

Cleveland: Knowledge-based industry

Cleveland, a city to the east of Toledo and also situated on Lake Erie, tells a different kind of economic transition story: a transformation from manufacturing to a new set of more knowledge-based industries including health care and education.

Cleveland was hit especially hard by international manufacturing competition and by the recession in the 1980s and 1990s. Over the past 23 years, the greater Cleveland metropolitan area lost nearly 90,000 manufacturing jobs, almost all in fields related to the automotive industry. [118] For Cleveland, which in 1990 had over 20% of its workers focused in the manufacturing sector (versus 12.6% in the "steel city" of Pittsburgh, another city highlighted in this report, and versus around 9% percent in the U.S. as a whole), this was a significant blow to the regional economy. In fact, experts have pointed to Cleveland as a city that was so overly focused on manufacturing in the late 20th century that it has been particularly slow to recover and shift to new industries and economic growth strategies in the first part of the 21st century. [119]

However, Cleveland is slowly transforming into a new, more knowledge-based economy, as the recent report from Cleveland State University and the group CEOs for Cities, "From Metals to Minds: Economic Restructuring in the Rust Belt," makes clear. The concentration of two major universities—Case Western Reserve and Cleveland State University—alongside two major hospitals have created a new economic development model focused on health technology. [120] The city has a highly educated workforce—Cleveland is ranked 10th in the U.S. in terms of the proportion of population with graduate degrees[121] —and boasts the 6th most hospital jobs of any city in the country, after the much larger metropolises of Los Angeles, Chicago, Houston, New York, and Boston.

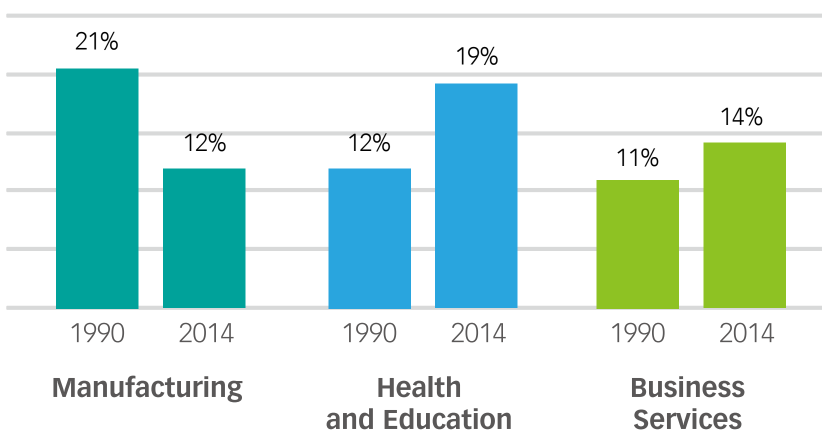
Cleveland Case Findings:

Problems: High unemployment due to severe downturn in auto manufacturing in the 1970s.

Solutions: Focused R&D spending through the region's research universities and medical institutions, leading to the creation of a regional medical cluster, building upon the strength of institutions that existed prior to the region's manufacturing downturn.

Results: Cleveland has become a leading center of medical services nationally, attracting firms and talented workers from around the region. The medical supply chains clustered around the Cleveland Clinic and Case Western Reserve University have become a major source of jobs, resulting in rising incomes.

CHANGES IN EMPLOYMENT SHARE BY SECTOR IN CLEVELAND (1990-2014)



While jobs in manufacturing declined, Cleveland saw a growth in health and education, and business services jobs.

Source: U.S. Bureau of Labor Services and St. Louis Federal Reserve, 2015

As a result of targeted R&D spending and strong existing educational and medical institutions, Cleveland has succeeded in creating a health care cluster similar to the economic high-tech clusters of the Silicon Valley, or biotechnology in the Research Triangle in North Carolina. As the *From Metals to Minds* authors state, discussing the recent move of Phillips Healthcare from San Jose, California to Cleveland, "[The] firm's relocation strategy was about the access to knowledge stemming from Cleveland's anchor institutions, particularly Case Western, Cleveland Clinic, and University Hospital. [122] " The city's cooperation with a private performing arts center, PlayHouse Square, to invest heavily in the downtown area has also brought younger and more educated workers back into the city center. [123]

Cleveland, in its move from a heavily manufacturing-based, undiversified economy to one more technology- and service-focused, may serve as a strong model for parts of the Jing-Jin-Ji region that are also searching for a "new normal" in economic planning. The lesson here is one of building the proper foundations for such an economic transformation: just as strong universities and hospitals form the basis of Cleveland's revival, strong education centers and related industrial clusters can anchor any transition in this region of China.

4.3 California: Clean and diversified growth

If it were a country, the U.S. state of California, with a Gross State Product of US$2.31 trillion, would be the 8th largest economy in the world—just behind Brazil but ahead of India, Canada, and the Russian Federation. [124] In 2014, California's economy performed better than the U.S. economy as a whole, increasing jobs by 2.8% (compared to a 1.8% increase nationally), and accounting for over 17% of all new jobs in the U.S. even though the state houses only 12% of the population. [125]

This impressive economic performance has come at the same time that California has been implementing some of the most far-reaching climate and energy policies in the world. In fact, the state's forward-looking policies have been one key factor in the growth of its clean technology sector, which in turn helped diversify California's economy to make it more robust. For this reason, California is an important example of a government working toward a truly sustainable economic growth model.

The state's oil refining and auto industries help illustrate how environmental regulation has gone hand-in-hand with innovation, without harming industry or prosperity. In the case of the oil sector, which forcefully argued against regulating car exhaust or fuel quality, regulations resulted in development of cleaner fuels such as reformulated gasoline and unleaded gas. [126] Studies of refineries in Los Angeles suggest that even though refineries had to pay between US$ 3-8 million per plant to meet air quality regulations between 1979 and 1992, during the same period their productivity increased sharply compared to similar facilities in the less-regulated U.S. Gulf Coast. [127] Similarly, to meet national emissions rules that car companies initially described as unreachable, the auto industry paired with companies like Corning and Johnson Matthey to develop the right combination of ceramics, precious metal catalysts, sensors, and fuel-injection for catalytic converters. [128] The

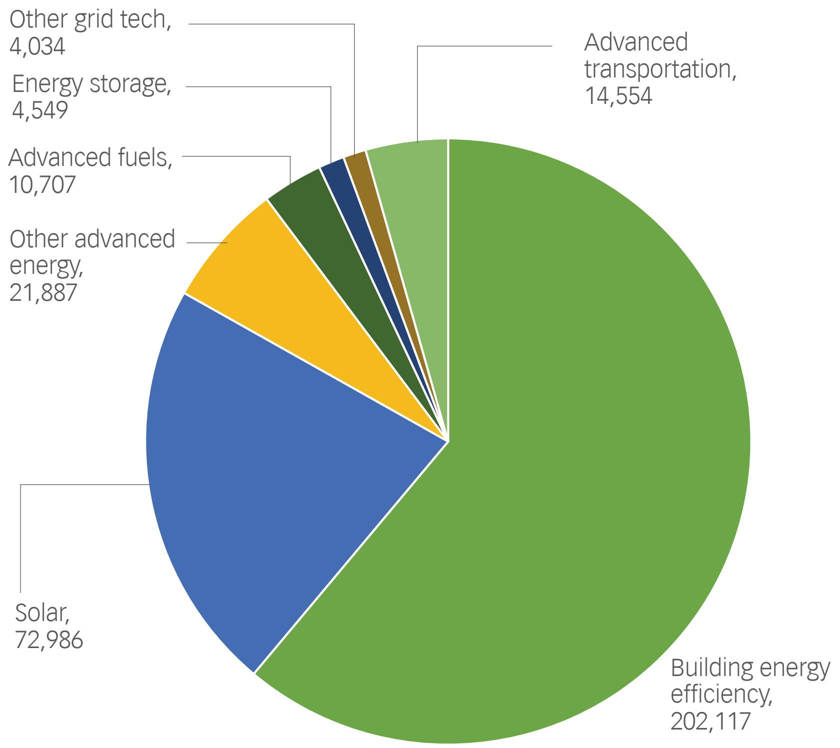
California Case findings:

Problems: Severe pollution in major cities, as well as high impact of climate change on the state's water supply.

Solutions: A series of interrelated policies to adjust the state's energy structure and encourage a shift away from fossil fuels, beginning with policies that reduced vehicle emissions and promoted renewable energy. More recently, interrelated policies have led to emissions trading for carbon dioxide and promotion of energy storage and vehicle electrification.

Results: California has not only become the leader in renewable energy deployment but has shown that aggressive policies to achieve environmental objectives can result in a major economic boost. California's policies have led to technology innovations from catalytic converters and advanced information technologies to aggregate energy storage resources to back up renewable energy generation.

ADVANCED ENERGY EMPLOYMENT IN CALIFORNIA, 2014



Employment in building energy efficiency far outnumber other jobs created in California's advanced economy, with solar a close second.

Source: California Advanced Energy Employment Survey, 2014

result was breakthrough innovation followed by years of steady improvement in tailpipe emissions control technology and policy. [129] All this came at a cost to consumers similar to that initially estimated by regulators, and with no apparent impact on vehicle sales or industry profits—despite increases in R&D to prepare for the changes. [130]

In 2006, California's legislature passed the Global Warming Solutions Act, which requires the state's regulatory agencies to achieve greenhouse gas emission reductions of about 25%, to bring emissions to 1990 levels. The two most significant elements of the bill, which is also known as Assembly Bill 32 or "AB 32," are (1) the statewide cap and trade program, which sets emission limits and allows emitters to trade permits in order to reach emission goals, and (2) the Low Carbon Fuel Standard, which requires a 10% reduction in the carbon intensiveness of fuels in the state by 2020. [131] These two policies, combined with a statewide Renewable Energy Standard [132] that requires 33% of all electricity sold in the state to come from renewable sources (excluding nuclear and big hydropower), and building efficiency standards that have been in place since 1977, [133] work together to make California a major market for innovative low-carbon technologies and services. In September 2015, the state built on the success of these programs by adopting new targets for achieving 50% renewable electricity production by 2030.

Estimating clean energy jobs is notoriously difficult for researchers, since so many jobs include clean energy elements (for instance, an electrician's job might include solar panel installation, but might also include basic wiring), and since the definition of "clean energy" might vary from model to model. However, in 2014, the NGO Advanced Energy Economy (AEE) conducted a survey of businesses and found that California has the most "advanced energy" jobs in the country, with over 430,000 jobs in the renewable energy, energy efficiency, and clean transportation sectors.* Of these, over 300,000 jobs are in the building energy efficiency sector, which is testament to California's strong building codes and standards. [134] The report projects job growth across advanced energy sectors of about 17% in 2015, compared to expected job growth across the state economy of only about 1%. [135] Another

Expert Voices: California

What factors have led California to be a leader in state level support for clean energy?

Ryan McCarthy: It stems from our history as a leader on regulating air pollution. We have always had some of the worst air pollution in the country, and were the first state to start regulating sources of air pollution. When the federal clean air act was signed in 1970, it gave us a unique authority to set our own standards and work to make sure our air was clean.** We still have some of the worst air quality in the country and we still need to take leading steps to promote clean technologies to comply with federal requirements. This history with air pollution and the natural beauty throughout our state that drives much of our lifestyle has led to diverse support across political and demographic lines for action on clean energy, as well.

To what extent have emissions policies led to investment and innovation?

Adrienne Alvord: We had a veritable flood of investment money pour in when Assembly Bill 32 – the bill that required California to develop regulations to reduce greenhouse gas emissions to 1990 levels by 2020 – passed in 2006. Venture capitalists came to California in droves to invest in clean energy, including biofuels, energy efficiency and solar energy. Our policies also brought a lot of people with interesting energy technology ideas to the state. All of this is because the state of California proved to people that we are serious about reducing emissions.

Ryan McCarthy: All of our regulatory policies work together in tandem. You can imagine addressing the two tasks of cleaning the air and addressing climate change separately, but it makes sense to do them together. For example, we are aligning transportation and climate change policy to make sure each addresses the other. As a result of these policies, there is a tremendous opportunity to stimulate investment in sectors where emissions reductions are needed: transit oriented development, low-carbon transportation, high-speed rail, and natural resources.

Ryan McCarthy,
Science and Technology Policy Advisor, California Air Resources Board

Adrienne Alvord
California and Western States Director, Union of Concerned Scientists

* For the purposes of the survey, the Advanced Energy Economy Institute defines an advanced energy company as a firm directly involved in researching, developing, producing, manufacturing, distributing, selling or implementing components, goods or services related to alternative fuels and vehicles; energy efficiency; renewable, nuclear and natural gas electricity generation; smart grid and other related technologies.

** Still today, California has the ability to impose standards on vehicle emissions that are tighter than those of the federal government. Other states can choose to adopt these tighter California standards once California has obtained a waiver from the federal government.

indicator of strong clean energy sector performance is that in 2014, California led all U.S. states in clean energy patent filings, with 385 patents filed in this category during the year. [136]

A testament to the strong clean energy technology market that California has created through policies and regulation is the fact that of the firms surveyed by AEE, 77% reported that their customers are predominantly within California. [137] California business leaders echoed the importance of strong policies to create positive conditions for business innovation and growth during a Paulson Institute-led discussion between Silicon Valley entrepreneurs and investors and Chinese mayors from Zhejiang Province. In particular, two leaders of clean technology firms on the panel made the case that they would not have located their firms in California if it had not been for these market-driving policies, particularly in the energy efficiency arena. [138]

California's clean energy policies are helping to create a more diversified economy for the state, which has suffered in the past due to over-dependence on one set of industries. At the end of the 20th century, the local economy was concentrated in real estate. By 2008, when real estate made up 16% of the state's economy, the housing bubble collapse and subsequent recession hit California particularly hard. [139] But today, California has expanded its share of what the Brookings Institution calls "advanced industries," including advanced energy. These industries rely on highly-skilled workers and tend to include research and development activities, and they are the anchors for the post-recession economic growth across the U.S. in the past few years. [140] The two major metropolitan regions of California—the San Francisco Bay Area and the greater Los Angeles region—are also home to some of the largest concentrations of these advanced industries in the U.S., and California as a whole has a significant presence in 14 out of the 50 advanced industries Brookings researchers studied. [141]

California represents a sustainable economy in the broadest definition of sustainability—both environmental and economic. As such, it offers valuable lessons to regions in China hoping to diversify and decarbonize their own economies. In particular, California's strong energy and climate policy framework has provided new and emerging clean energy businesses with a strong market for their products, which has helped to establish this state of 38 million people as one of the top choices for clean energy start-ups in the world.

The lessons for Hebei from California and the American Rust Belt are diverse. In many cases, the differing fates of Pittsburgh, Ohio and California resulted from basic differences in geography, resources and economics. The Paulson Institute believes the following key lessons from the case studies are valuable for Hebei's transition:

- **Economic diversification is a key ingredient to economic transition.** Overconcentration is risky, especially when it involves concentration of industries with large numbers of workers with lower educational backgrounds. Automation and international competition hit the U.S. Midwest particularly hard, and it took a period of crisis for cities like Cleveland and Pittsburgh to recognize that manufacturing jobs would never recover to prior levels—and they would need to look elsewhere for growth.

- **Leading educational institutions and public-private collaboration can help speed transitions.** Not all cities have the resources needed to become high-tech clusters. Cities with a legacy of educational institutions, leading companies, and a culture of entrepreneurship are more likely to succeed.Thoughtful and targeted R&D spending decisions by top-ranked educational institutions can be decisive in establishing successful regional clusters—such as solar in Toledo and computer science and health care in Pittsburgh. In both Pittsburgh and Cleveland, regular public-private collaboration helped set local and regional planning strategies that were key to attracting the right talent and workforce to sustain a successful economic transition.
- **Policy leadership on energy and the environment can create new economic opportunities for a region.** The state of California has experienced rapid growth over the past few years at the same time even as it implemented a series of far-reaching energy and environmental policies. Rather than waiting for technologies like solar, energy storage, or electric vehicles to mature, the state has implemented a series of carefully designed energy and environmental mandates—coordinated with industry to ensure they are achievable, but well in advance of similar policies in other regions. California has also coordinated environmental policy with innovation in new energy, directing funds raised from auctions of emissions allowances to support deployment of solar and electric vehicle charging infrastructure.

Economic and Environmental Harmony: California's environmental regulations boost innovation, and the state has one of the best performing economies in the U.S.

5. CONCLUSIONS

China's Jing-Jin-Ji region has the opportunity to transition in a way that makes sense for both the economy and the environment.

The Chinese and U.S. examples above illustrate two important themes: First, that economic and environmental prosperity can go hand in hand, and second, that economic transition in industry is a key element of achieving China's environmental goals. Through studying successful efforts now underway in China, as well as cases of economic transition and environmental improvement in the U.S., China's leaders have the potential to speed the transition of the Jing-Jin-Ji economy towards a cleaner and more prosperous future.

To some extent, China's environmental and energy policies are inseparable from larger economic forces. China has embarked on an ambitious program to clean the air, shift away from coal and other polluting industries, and transform the nation into a high-technology, high-innovation, high-income economy. Industrial transition is also key to achieving the Jing-Jin-Ji region's environmental objectives: As this paper shows, cutting industrial emissions has a larger impact on the region's ambient air quality than policies directed at any other sector. Furthermore, while many might assume that the only way to cut industrial emissions is to simply scale back production, modeling shows that efficiency and productivity improvements within industry could have an immense impact on reducing emissions of both PM2.5 and carbon dioxide.

Not only can old industries clean up, but new industries are rising to serve the needs of China's cleaner economy. China is already pursuing a variety of policies that support clean energy, and some—such as distributed solar and energy-efficient building technologies—are already reaching the Jing-Jin-Ji area. While China is already taking the lead in many areas of clean energy development, there is still much that local leaders can learn from cases of economic and environmental policy transitions in the U.S. The American experience shows how a mixture of energy and environmental policies can promote long-term growth, as well as create new jobs. [142]

China's Jing-Jin-Ji region has the opportunity to transition in a way that makes sense for both the economy and the environment. We are excited to witness these positive developments taking place in Jing-Jin-Ji as governments move forward with their plans and create bright futures for the nation's people.

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