CHINA

World Bank Group
Overview

COUNTRY CLIMATE AND DEVELOPMENT REPORT

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OVERVIEW

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Overview

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Overview
The China Country Climate and Development Report (CCDR) provides analysis and recommendations on integrating the country’s efforts to achieve high-quality development with the pursuit of emission reduction and climate resilience. Without adequate mitigation and adaptation efforts, climate risks will become a growing constraint to China’s long-term growth and prosperity, threatening to reverse development gains. Conversely, if efforts to tackle climate risks lead to a significant decline in growth and rising inequality, they would deprive millions of people of development and likely erode support for the reforms necessary to achieve a lasting economic transformation. Hence, China will need to grow and green its economy at the same time. This report offers policy options to achieve these dual objectives by easing inevitable trade-offs and maximizing potential synergies between China’s development and climate objectives.

Table O.1. Different Measures of China’s Carbon Footprint

<table>
<thead>
<tr>
<th>Country</th>
<th>CO₂ Emissions per Capita (Tons per person)</th>
<th>Emission Intensity (kg per PPP $ of GDP)</th>
<th>Total GHG Emissions (Mt of CO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>5.0</td>
<td>0.13</td>
<td>1057.3</td>
</tr>
<tr>
<td>China</td>
<td>9.0</td>
<td>0.46</td>
<td>12705.1</td>
</tr>
<tr>
<td>India</td>
<td>2.5</td>
<td>0.26</td>
<td>3394.9</td>
</tr>
<tr>
<td>Indonesia</td>
<td>3.7</td>
<td>0.19</td>
<td>1002.4</td>
</tr>
<tr>
<td>Philippines</td>
<td>2.2</td>
<td>0.14</td>
<td>234.3</td>
</tr>
<tr>
<td>Russia</td>
<td>17.2</td>
<td>0.39</td>
<td>2476.8</td>
</tr>
<tr>
<td>United States</td>
<td>18.3</td>
<td>0.23</td>
<td>6001.2</td>
</tr>
<tr>
<td>Vietnam</td>
<td>4.7</td>
<td>0.33</td>
<td>450.1</td>
</tr>
<tr>
<td>European Union</td>
<td>7.6</td>
<td>0.13</td>
<td>3383.4</td>
</tr>
<tr>
<td>OECD</td>
<td>10.7</td>
<td>0.18</td>
<td>14551.2</td>
</tr>
</tbody>
</table>


China’s development and climate change are deeply and increasingly intertwined. The country is both a contributor to rising global greenhouse gas (GHG) emissions causing climate change and severely affected by its adverse impacts. Although China is not the main source of historical cumulative emissions, it today accounts for 27 percent of annual global carbon dioxide and a third of the world’s greenhouse gases emissions (Table O.1). Alongside other larger emitters, China’s contribution to reducing global climate risks is therefore crucial. Reducing greenhouse gas emissions in its relatively carbon-intensive industrial economy will not be easy, posing transition risks but also opening new opportunities for development. At the same time, large parts of China’s population and economic infrastructure are heavily exposed to climate risks. China, like other countries, will have to adapt and build resilience to protect human life and avoid economic losses from the effects.

The CCDR is firmly anchored in China’s own development and climate aspirations. China aims to sustain sufficient economic growth to double per capita income and become a high-income country by 2035. Simultaneously, recognizing the long-term threat climate change poses to its own and to global development, China has also made ambitious commitments to peak carbon emissions before 2030 and achieve carbon neutrality before 2060. This report is, therefore, not about whether China should act to address climate change but how it can do so while safeguarding development gains and ambitions.
China’s climate ambition and development opportunity

Climate change poses a significant threat to China’s long-term growth and prosperity. Rising sea levels and risks related to coastal flooding, storm surges, and coastal erosion threaten China’s densely populated low-elevation coastal cities, which account for a fifth of China’s population and a third of its gross domestic product (GDP). Meanwhile, interior provinces in northern and western China are exposed to more frequent and extreme heat waves and droughts which intensify water security risks and impact agriculture—a major source of income, especially among China’s rural poor. No longer threats in a distant future, these risks are already starting to materialize today, as evidenced by recent floods and droughts that have devastated large parts of the country. Direct annual losses from natural hazards are estimated to have averaged US$76 billion over the past five years. Studies indicate that these effects will only intensify, with estimates suggesting that climate change could result in GDP losses of between 0.5 and 2.3 percent, as early as 2030. Worryingly, these impacts will disproportionately hit the bottom 40 percent of the income distribution, who could incur losses of up to 4.7 percent of their income by 2030, in the most severe climate scenario (Figure O.1.a and b).

Figure O.1. Climate change poses a major threat to China’s economy and livelihoods

Source: Hallegatte et al. (2017), Shockwaves modeling for China.

Note: The bars in each graph represent ranges that correspond to alternative socio-economic and climate change scenarios.

Meanwhile, China’s economy is also confronting growing economic imbalances that constrain future growth. After decades of high-speed growth, China’s growth has gradually slowed over the past decade, reflecting looming demographic headwinds and a sharp decline in productivity growth (Figure O.2.a). The economy has become overly reliant on investment, especially in carbon-intensive infrastructure and real estate, with rapidly diminishing economic returns (Figure O.2.b). China’s economy also remains more dependent on industry than do countries at similar levels of per capita incomes, partly due to the large presence of state dominated heavy industries—in the steel, cement, and other construction materials sectors—and partly because of its dominant role in many global value chains. Aiming to shift from high speed to high quality growth, China needs to rebalance its growth model—from traditional infrastructure investment to innovation, from exports to domestic consumption, from industry to high-value services, from high to low carbon intensity, and from state-led to more market-driven allocation of resources.
China’s increasingly factor-driven growth model is facing constraints. While addressing climate risks is imperative to securing long term development, achieving China’s climate and development goals will be uniquely challenging: it will require decoupling economic growth and emissions at a faster pace and at a lower income level than in advanced economies (Figure O.3.a). This will entail fundamental structural changes of the economy: China’s energy, industrial and transport systems, its cities, and land use patterns will have to undergo dramatic transformations. Energy prices will likely increase—at least in the short run—with detrimental impacts on consumers and firms. A large part of China’s existing carbon-intensive capital stock will become obsolete, and job losses will occur in polluting industries, many of which are concentrated in some of China’s poorer interior provinces. The resulting disruptions and dislocations—and their impact on growth and inclusion—are serious concerns that need to be addressed to move forward on an economically, socially, and politically viable decarbonization path. The good news is that aggregate adjustment costs and distributional impacts depend at least partly on the policy mix adopted.

China’s transition to carbon neutrality will require decarbonization at a lower income level and at a faster pace than other major economies (Figure O.3.b).
Yet, China is also well positioned to turn climate action into an economic opportunity. Like previous transformations on the scale envisaged, the transition to reduced carbon intensity and climate adaptation in China and the rest of the world will unlock new sources of economic growth, innovation, and job creation, with the added benefit of lowering China’s reliance on imported fuels and enhancing its energy security. As a global manufacturing hub, China—and especially its private sector—is uniquely positioned to take advantage of these shifts. China is at the forefront of advancing low-carbon energy supply and mobility. It has one-third of the world’s installed wind power and a quarter of its solar capacity. Already today over 4 million jobs—more than half of the global total in renewable energy—are in China. Fueled by its large domestic savings, China is also becoming a leader in green finance, being home to the world’s largest green bond and credit markets. These opportunities are also real. But, as in the case of transition costs, whether they will be realized crucially depends on policies.

Charting pathways to resilient, carbon-neutral growth

Model-based simulations, consistent with China’s “30-60 goals” and Nationally Determined Contribution (NDC), show that the pace of emissions reduction will vary across sectors, with important implications for sequencing (Figure O.4). The low-carbon transition of the power sector—the largest source of emissions—would need to come first to achieve a rapid decline in emissions over the next two decades. Frontloading the decarbonization of the power sector is also important to meet growing electricity demand, including from electrification of demand sectors, such as transport, buildings, and industry without increasing emissions. Investments in available least-cost options in domestic solar and wind, supported by expanded energy storage would steadily reduce coal use in the power sector. In the industrial sector, reduction of excess production capacity, energy efficiency improvements, and electrification would lower emissions in the short term, but innovations such as green hydrogen and carbon capture, usage, and storage (CCUS) would be required to achieve deep decarbonization in the long term. In the transport sector, carbon intensity would be reduced through continued investments in public mass transport systems, electrification as well as innovations in low-carbon fuels for hard-to-electrify modes. Direct CO₂ emissions from buildings would be mitigated through electrification, clean district heating, and energy efficiency. Finally, carbon sequestration—negative emissions—from nature-based solutions (NbS), including expanded forest coverage, will enable carbon neutrality by offsetting significant residual emissions in hard-to-abate sectors while simultaneously favoring resilience to floods, droughts, and sea-level rise.

Decarbonization will require significant investments in a massive green infrastructure and technology scale-up. Specifically, our sectoral models suggest that China would need a total of about US$14 trillion in additional investments from now until 2060 for the power and transport sectors alone, equivalent to 0.97 percent of GDP
during that period (see Table O.2). To avoid locking-in carbon intensive assets and meet China’s NDC targets, a large part of these investments would need to be frontloaded, requiring about US$2.1 trillion (equivalent to roughly 1.1 percent of GDP) in the next decade. Under an accelerated decarbonization scenario that would allow emissions to peak earlier than 2030, reducing cumulative carbon emissions until 2060 by almost 55 billion tons and smoothing the impacts on GDP over time, investment needs would increase by US$3 trillion to a total of US$17 trillion. While overall investment needs are largest in the transport sector, many of the investments in the sector are expected to bring about significant energy efficiency gains and operating cost savings that would make these investments not only economically viable but financially attractive. In addition, technological progress may lower some of these costs, and individual investments and the policies to encourage them may be prioritized (or de-prioritized) taking also into account specific cost-benefit considerations. Public investments will be necessary but not sufficient to meet the overall investment needs. They will need to be complemented by good sector policies, broad-based regulatory reform, and new standards to fully tap the potential and incentivize private sector investment and innovation in these sectors.

The aggregate macroeconomic impacts of decarbonization are manageable and crucially depend on policy choices. The model-based simulations suggest cumulative GDP losses/gains of between -2.0 and 0.3 percent, depending on the specific policy choices and model specifications to achieve carbon neutrality before 2060. Beyond these estimates that are subject to high uncertainty, three policy relevant findings emerge from the modeling: First, aggregate economic impacts of achieving China’s NDC in the next decade could be marginally positive, reflecting the availability of low-cost abatement options in the power sector and industrial energy efficiency. Second, the simulations also suggests that adjustment costs could be reduced significantly if labor market frictions are addressed, reinforcing the importance of complementary structural reforms. Finally, the upper bound of the estimates illustrates that decarbonization policies could even boost growth if labor productivity gains from improved air quality and public health are accounted for.

Table O.2. Investment needs to achieve China’s NDC and carbon neutrality

<table>
<thead>
<tr>
<th>Incremental investment over reference case</th>
<th>2021-25</th>
<th>2026-30</th>
<th>2031-40</th>
<th>2041-50</th>
<th>2051-60</th>
<th>Total</th>
<th>NPV (6%)</th>
<th>NPV (Risk-free)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity (Generation and Grid)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-carbon mode Infrastructure</td>
<td>336</td>
<td>368</td>
<td>1,386</td>
<td>1,992</td>
<td>200</td>
<td>4,282</td>
<td>1,757</td>
<td>2,588</td>
</tr>
<tr>
<td>Fuel and operating efficiency</td>
<td>-224</td>
<td>413</td>
<td>1,471</td>
<td>370</td>
<td>-102</td>
<td>1,928</td>
<td>843</td>
<td>1,263</td>
</tr>
<tr>
<td>Electrification and fuel switch</td>
<td>282</td>
<td>897</td>
<td>3,029</td>
<td>1,951</td>
<td>1,242</td>
<td>7,403</td>
<td>2,979</td>
<td>4,419</td>
</tr>
<tr>
<td>Total</td>
<td>403</td>
<td>1,727</td>
<td>5,964</td>
<td>4,347</td>
<td>1,359</td>
<td>13,800</td>
<td>5,668</td>
<td>8,394</td>
</tr>
</tbody>
</table>

Source: Bank internal analysis. GDP projections are the same as in the baseline CGE scenario.

Note: NPV (Risk-Free) is calculated based on the yield curve of China’s treasury bonds, ranging from 2.0 percent for the 1-year bond to 3.4 percent for the 50-year bond.

The relatively benign aggregate impacts are no cause for complacency about transition risks. The model simulations show that costs of the low-carbon transition affect the poor disproportionately and are regionally and sectorally concentrated. Higher energy prices lead to a substantial loss in households’ purchasing power across the distribution with poorer households facing larger impacts (Figure O.5). Lower employment and earnings among agricultural workers will affect low-income households, whereas job losses, and lower earnings in industry will impact households in the richer quintiles. Some of China’s poorest regions, which are more dependent on carbon-intensive economies, will be hardest hit. The north and northwestern provinces of Xinjiang, Inner Mongolia, Shanxi, Shaanxi, Ningxia, and Liaoning would experience the greatest emissions declines, negative employment, and output effects. By contrast, the low-emissions provinces of Tianjin, Guangdong, Jiangsu, and Zhejiang face the best outcomes, closely followed by Beijing and Shanghai. Recycling part of the carbon tax revenues into social support to households, workers, and communities negatively affected by the transition could help stem rising inequality.

**Figure O.5. Distributional Impacts of Decarbonization**

Regressive impacts of climate action can be addressed

Welfare impacts by income groups, 2060 (% relative to baseline). Decomposition by income source.

Source: World Bank staff estimates based on MANAGE.

**What we recommend**

Balancing China’s development and climate objectives will require broader structural and market reforms to complement climate action. Climate policy action is necessary to adjust relative prices—either through explicit carbon pricing or regulation and foster low-carbon innovation and technology adoption. Government policies will also have to foster investments—both private and public—in climate-proving infrastructure and social safety nets. But the effectiveness of these policies depends on competitive markets to create the right incentives for market participants to undertake investments and stimulate innovation in green products and technologies. Although China’s economy has become more market-driven, there are remaining distortions in both factor markets and key product markets (for example, energy). These distortions have contributed to misallocation of resources and stifled competition, weighing on productivity growth but also contributing to relatively high carbon intensity. Unless addressed, they could become impediments for an efficient transition process. Structural reforms to promote a market-based allocation of capital, labor, and land and to facilitate the smooth entry and exit of companies would enable the economy to adapt more efficiently to changing price signals and regulations, thereby lowering adjustment costs. They would also help enhance the economy’s shock absorption capacity to physical risks. Adopting climate actions within such comprehensive policy framework would help ease the inevitable trade-offs and maximize the potential synergies between China’s climate and development objectives. The specific policy options presented in this report can be structured around six interconnected policy packages.
Policy Package 1: Accelerate the power sector transition with market reforms and investments in renewables

The low carbon transition in power and heat generation between now and 2030 is pivotal in driving decarbonization. This transition is both feasible and necessary. It is feasible because of the availability of increasingly cost-competitive renewable energy technologies. And it is necessary because electrification in end-use sectors—transport, housing, and industry—will require a growing supply of clean electricity to achieve intended emission reductions. While investments in the rapid scale-up of renewable capacity are essential, structural reforms to create more integrated and efficient electricity markets would help ensure efficient utilization and integration of renewable generation assets. It would also help attract more private sector investment and innovation.

- Implement scale up of solar and wind power generation capacity to 1,200 GW by 2030, in line with China’s Nationally Determined Contribution (NDC). While this envisaged scale up is ambitious, analysis undertaken for the CCDR shows that adding more renewable energy capacity, up to 1,700 gigawatts (GW), could advance emissions peaking to earlier than 2030 and result in a significant reduction in cumulative emissions. To do so, China would need to add up to 120 GW of solar and wind capacity every year by 2030, 1.5 times the annual average during 2016–20 and 20 percent more than the capacity addition in 2021. This would enable China to meet incremental electricity demand with renewable energy and reduce coal-based generation from 2025 onwards. This is an ambitious target. Achieving it would require a strong global supply response and increased production capacity for battery and solar/wind components to reduce pressure on prices for these technologies.

- Adopt international best practices in system planning, reliability regulations, and variable renewable energy (VRE) generation forecast and dispatch to reduce the need for additional coal-fired generation capacity. Increasing the capacity value for VRE in line with standards used internationally would result in less need for additional new coal capacity. Moreover, VRE dispatch can be further optimized by adopting advanced short-term weather forecasting and digitalization at the provincial grid level.

- Accelerate the integration of provincial and regional power markets to optimize overall capacity usage. Integrating provincial grids would allow one province to take advantage of reserve capacity in other provinces and reduce the need for additional coal power capacity. This would require both physical investments in interprovincial transmission lines and reforms to move dispatch operation and responsibility from the provincial to the regional or national level. The authorities are aiming for a unified national power market by 2030. Accelerating market integration could help reduce the costs of the energy transition.

- Expedite electricity market reforms. China has gradually moved toward a greater role for market-based transactions in the power sector. A complete phasing out of quotas for coal-fired power plants, along with the introduction of a market for ancillary services, would encourage greater private investment in renewables and storage capacity and facilitate the shift of coal power plants to peak load. Together with effective carbon pricing through a tightening of the emissions standards under China’s emissions trading system (ETS), electricity market reforms would optimize system cost, enhance flexibility, level the playing field for renewable energy, and shift the role of China’s large existing coal fleets.

- Promote demand management measures for electricity use and heating. Regulatory measures and time-of-use retail tariffs could help drive further improvements in energy efficiency. China could also promote distributed renewable energy and storage to take some load out of the grid, establish demand response programs where consumers are paid for voluntary load control, and develop smart grid and electric vehicle-to-grid applications that further decrease peak demand and increase grid flexibility. In the heating sector, prices remain well below cost recovery and the limited use of consumption-based billing reduces incentives for energy savings, with the resulting subsidies benefiting richer households with larger dwellings disproportionately. Targeted support to the poor may be needed, however, to address affordability concerns if tariffs are adjusted to reflect costs.
Policy Package 2: Decarbonize key energy demand sectors—industry and transport

Decarbonizing transport

Transport sector GHG emissions are growing fastest among all sectors. If unmitigated, transport emissions would peak in 2040 at about 150 percent of the current level, much later than China’s target overall peaking year of 2030, before decreasing to the current level by 2060. Decarbonizing the transport sector requires concerted efforts encompassing policies, pricing, regulatory measures, infrastructure investments, and technological innovation, through which motorized trips can be avoided or shifted to lower energy-intensity modes, or their energy efficiency improved.

- **Advance electrification beyond public transport vehicles to include the private and commercial fleet.** Electric vehicles in China take up less than 2 percent of the total fleet and are concentrated mostly in the largest urban areas. Given rapid motorization trends driven by rapidly rising incomes, early action could mitigate risks of costly and emission-intensive lock-in in fossil fuel technologies. During the initial market development, public policies may be needed to ensure price parity (through taxes and incentives), but these interventions should be temporary and need to be carefully designed. Scaling up charging infrastructure by enabling private investment is equally important. Early actions to advance electrification would be critical for advancing emissions peaking in transport, from 2040 or later under the business-as-usual scenario to 2030–35, bringing about an emissions reduction of about 14.0–18.4 Gt from now until 2060. While electrification can achieve some emission reduction even with China’s existing power mix, as pointed out above, frontloaded decarbonization of electricity supply is crucial to realize the full abatement potential of electrification in the sector.

- **Combine regulatory measures with pricing instruments to encourage fuel and energy efficiency improvement by the private sector.** China has effectively implemented administrative measures toward stricter fuel economy and energy efficiency standards of vehicles over time. These regulatory tools, combined with higher fuel taxes or carbon pricing, would provide strong incentives to private and commercial fleet operators to reduce fuel consumption, which is estimated to bring about an emissions reduction between 4.3–7.0 Gt from now until 2060.

- **Promote modal shifts from private road transport to public mass transit (for passenger transport) and to railway and waterway (for freight transport), through deeper integration across modes and pricing incentives.** Despite the success in rapidly building an extensive network of high-speed railways and urban metros, the integration between modes has been weak due to the lack of institutional coordination. The current pricing structure results in lower relative prices for carbon-intensive modes (road and air transport) compared to lower-carbon modes (rail and waterway). Meaningful shifts to low-carbon modes, which require both physical and operational integration across modes and relative pricing that reflects externalities, can bring about an emissions reduction between 2.4–3.3 Gt from now until 2060.

- **Promote technology development for alternative low-carbon fuels for harder-to-decarbonize sectors.** Waterborne and air transport systems, which account for about 15 percent of transport emissions and are growing fast, are difficult to electrify with current technologies. Alternative options, including green hydrogen, ammonia, and potentially new generations of batteries, are not yet commercially viable. Continued innovation will be required to achieve full decarbonization of the transport sector by 2060 in line with government targets.

Decarbonizing industry

Industrial energy efficiency in China has improved steadily over the years, but greater progress is possible. Although the growth rate of industrial process emissions has been declining since 2005 thanks to rapid improvements in energy efficiency, decarbonizing China’s large heavy industries will be challenging because low-carbon production technologies remain costly (for instance, use of hydrogen and carbon capture in steel production) or do not yet exist (as in cement-production). A structural shift away from heavy industries, a
move toward a circular economy, and the development of new technologies, including carbon capture and storage (CCS), will be required to bring industrial emissions down.

- **A shift from traditional investment-led towards more consumption driven growth would reduce trade-offs between the authorities’ short-term growth and long-term climate objectives.** China has traditionally relied heavily on investment to drive growth. This investment-driven growth model has stimulated demand for steel, cement, and other carbon-intensive outputs of heavy industries and thereby increased emissions. The economic returns to investments especially in infrastructure and real estate have been declining. Instead of stimulating further accumulation of physical capital, using government policies to support consumption would be consistent with China’s objective of economic rebalancing toward services and consumption while simultaneously mitigating the trade-off between short-term growth and ambitious emissions targets.

- **Greater attention to circular economy opportunities would reduce emissions intensity and help overcome material supply bottlenecks.** Promotion of the circular economy can support emissions reductions. Electric Arc Furnace (EAF) production is currently constrained by domestic scrap steel supply. A standardized scrap steel recycling system would facilitate increased use of scrap, important in the context of China’s end-of-life steel availability quantities, which are expected to double over the coming decade as existing infrastructure reaches end-of-life. At the same time, tighter design standards for new buildings can be used to mandate more recycled content.

- **In the longer term, there is a need to support direct and indirect drivers of technological advancement.** A range of technologies is available to reduce emissions but requires price incentives to support uptake. Technologies available range from well-established to experimental and can dramatically reduce emissions (Lin et al. 2021). Background analysis of firm-level data in China’s major industries, undertaken for this report, demonstrates the correlation between research investment, technological innovation, and industrial efficiency across sectors. It also highlights the role of foreign investment in driving efficiencies by diffusing advanced management experience and cleaner technologies. The planned expansion of the ETS will motivate efficiency measures when it is expanded to cover areas of the economy beyond power generators.

- **Decarbonizing the industrial sector may also induce relocation of industries toward provinces with higher renewable energy potential.** China’s industrial capacity, especially its carbon-intensive heavy industries, is spatially concentrated in the northwestern provinces, reflecting historical industrialization patterns that were in part driven by the endowments with carbon-intensive energy sources (such as coal). The low-carbon transition may shift comparative advantages to areas with high renewable energy potential (solar, wind, hydro) and fuels derived from these inputs (hydrogen, ammonia). This will likely reshape the economic geography. Enabling flexible factor markets could ease this relocation where it contributes to most cost-effective low-carbon production.

**Policy Package 3: Enhance climate resilience and low-carbon development in rural landscapes and urban areas**

Despite progress in setting a national policy framework, there are opportunities to improve adaptation efforts at both the national and sector levels. Fortunately, mitigation and adaptation actions are synergetic in several areas, such as city planning; agricultural, water, and land management practices; the development of green finance; nature-based solutions (NbS); and the creation of an offset market, together with building more resilient social protection systems.

*Low-carbon and resilient rural landscapes*

Physical risks from climate change will affect the country’s agricultural production potential and the availability of ecosystems services such as water yield, erosion control, and carbon sequestration. Changes in crop yields and the availability of arable land will affect agricultural output and could increase risks, unless

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2 Background note on determinants of industrial eco-efficiency, prepared by Yutao Wang et al. (Fudan University).
production practices are adapted to climate change. Water resources are already being impacted by climate variability, and climate change will severely affect China’s water systems. Meanwhile, agriculture, together with land use, land-use change, and forestry (LULUCF), accounts for 6 percent of emissions, although this has declined over the past decade.

**Nature-based solutions, such as afforestation, forest management, nutrient management, improved grazing land management, and wetlands restoration, offer opportunities to contribute to climate change mitigation and resilience.** Preliminary estimates suggest the potential to remove at least 768 Mt of CO$_2$ equivalent annually (CO$_2$ yr$^{-1}$) by 2030 through NbS in China. This could offset difficult-to-mitigate emissions, reducing total costs of achieving carbon neutrality. NbS can also deliver potentially large co-benefits, in terms of ecosystems, watershed management, and pollution reduction. Research prepared for the CCDR suggests that land-based carbon sequestration could be improved by 33.9 percent with no net decrease in food production, although some switching of land use is required.

- **Elevate NbS within the national climate change planning process and use carbon credits to leverage new sources of financing.** There is a need to reflect the potential of NbS in high-level planning, and explicit targets should be set toward the 30-60 goals. Unlocking NbS potential will also require new sources of financing; carbon credits in conjunction with the ETS could be harnessed for this purpose. Public funding will continue to be necessary but spending effectiveness could be improved. Public eco-compensation programs (over US$30 billion annually), for example, could be conditioned on ecosystem outcome proxies (for example, plantation diversity) rather than outputs (plantation area) with tighter spatial targeting (that is, prioritizing areas with the highest biodiversity and carbon sequestration potential) and use of reverse auction mechanisms. In addition, the introduction of China’s emissions trading scheme (ETS) provides an opportunity to finance NbS through the sale of carbon offsets.

- **Reduce China’s food system-related greenhouse gas (GHG) emissions by repurposing agricultural public support, reducing food loss and waste, and recycling.** This would entail decreasing expenditures coupled with production and using the fiscal savings to support the development of green technology in R&D expenditures. R&D expenditures include technologies that mitigate GHG emissions; alleviate soil and water pollution from fertilizer, pesticide, plastic film, and livestock and poultry waste; reinforce climate adaptation and disaster resistance; and increase the efficiency of natural resource use (land and water). Green subsidies should be designed with clear and conditional environmental requirements for potential recipients. Only producers who meet the environmental requirements or set standards should receive subsidies.

**Low-carbon and resilient cities**

**Cities in China play an important role in realizing climate and development goals.** The urbanization rate, currently at 60 percent, is projected to reach 80 percent in 2035, with an expected urban population of over 1 billion. Cities are expanding more rapidly in areas exposed to climate risks. Moreover, sea-level rise and storm surge constitute a serious and imminent threat to Chinese coastal cities and infrastructure. At the same time, urban built-up areas currently represent up to 90 percent of total CO$_2$ emissions in China. While population density has fallen steadily in recent years, our analysis shows that lower urban population density is associated with higher per capita emissions (Figure O.6). Reversing this trend and creating conditions for denser, well-connected, and people-oriented cities would be good for the climate while seizing the full productivity benefits of urban agglomeration. Moreover, urban NbS, such as harnessing wind cooling to deal with urban heat traps, using natural water bodies for flood control, and creating integrated green urban spaces to preserve biodiversity, can enhance climate resilience while making cities more livable.
Promoting denser, well-connected, and people-oriented urban growth. Urban planners have a number of tools at their disposal to achieve a low-carbon urban growth path, including: (i) regulatory measures such as floor area ratios to influence the density of development, (ii) land use regulations to discourage urban sprawl and promote compactness, (iii) coordinated urban expansion and public transport investment strategies to encourage transit-oriented development, (iv) area master plans to promote walkable neighborhoods and small-block development, and (v) scaling up of urban re-densification and regeneration programs. The dependence of China’s cities on land sales for revenues has encouraged sprawl, and the introduction of property taxes and alternative sources of local revenues could thus greatly encourage densification of urban areas with lower emissions and enhanced productivity.

Combine grey and green solutions and engage local planning authorities to protect critical public assets against floods, storm surge, and sea-level rise. Policy measures could include the enhancement of early warning systems, planning and investing in the restoration of coastal mangroves, and investing in improved drainage. Moreover, to maximize the benefits for communities, city governments should involve local residents in the implementation process to not simply raise awareness, but also to leverage community resources for disaster prevention and response.

Strengthening city-level GHG inventories and related analytics would be crucial to help cities identify key emissions reduction potential and monitor progress toward the achievement of carbon goals. Methodologies for GHG accounting also need further standardization across cities, to facilitate emissions trading and guide private investment.

Strengthen fiscal incentives and financial and building regulations to encourage private investment in more energy-efficient buildings. Aligning domestic building standards with international norms could attract more investment, including from the growing green finance pool. More reliable monitoring and disclosure of building energy efficiency could inform investors, regulators, and homeowners/occupiers. It would also allow a shift of existing fiscal incentives for the building sector to incorporate ex-post performance measures for energy conservation and emissions reduction. Finally, building carbon emissions could be included in the carbon trading market system.
Cross-cutting institutional reforms for adaptation

China’s adaptation policy landscape remains fragmented. The current regulatory system provides limited information and incentives for private actors to prepare for and insure against the effects of a warming climate. National policies lack a coherent effectiveness evaluation framework, while the use of quantitative targets and monitoring systems on climate adaptation at the local level is limited.

- **Identify, monitor, and fill gaps in the adaptation capacity of people, firms, and local governments.** A first step would be to make existing databases on climate vulnerability more broadly accessible to government and nongovernment actors. Local governments lack the capacity and knowledge to implement more resilient policies and engage residents on the ground. Governments at the subcity district level could benefit from peer learning and collaboration between urban and rural districts to jointly address climate change-related risks. This could be accompanied by the development of an adaptation effectiveness evaluation framework. With improved data availability on disaster risk and adaptation capacity, private insurance markets can set appropriate incentives and help mobilize funding for risk mitigation.

- **Improve the targeting of social transfers to address climate vulnerabilities.** Food price shocks and climate change-induced agricultural production shocks will be key challenges faced by the vulnerable populations in China over the next few decades. Risk mitigation measures include strengthening farmer cooperatives, fostering the adoption of climate-smart agricultural practices, improving access to climate insurance and small agricultural loans, enhancing off-farm income and employment opportunities, and investing in quality education and training services. In addition, targeted transfers will be needed to prevent vulnerable rural households from falling back into poverty.

Policy Package 4: Harness markets to drive cost-effective economy-wide abatement and innovation

The transition to carbon neutrality will require the use of well-designed economy-wide policies. Economy-wide policies are important to deal with market failures and ensure relative prices reflect both the social cost of carbon and the public benefits of low-carbon innovation and technology diffusion. But achieving carbon neutrality will require more than adjustments in relative prices. Broader structural reforms to promote a more decisive role of market forces in guiding the allocation of capital, land, labor, and R&D investment are hence critical to enabling the economy to adapt more efficiently to changing price signals and regulations.

- **Expand the role of carbon pricing with forward guidance.** Simulations show that a more broadly applied and higher carbon price rising to US$50–75 per ton of carbon by the end of this decade could help reduce China’s emissions by about 15 to 20 percent. To move in this direction, China could strengthen the ETS design with a total emissions cap with pre-announced annual emissions cap reductions, aligned with China’s desired emissions reduction path. This would allow investors to factor future carbon price increases into their investment decisions today. Over time, the ETS should also be expanded to other emitting sectors, as planned, and could be complemented by carbon taxation in sectors in which ETS implementation is not feasible. The efficacy of the ETS or any other form of carbon pricing will also hinge upon the successful implementation of market reforms in the power sector (discussed above).

- **Deepen state-owned enterprise (SOE) reforms to enhance competition, productivity growth, and emissions reduction.** SOEs are estimated to generate about half of China’s total greenhouse gas emissions, given their dominant presence in carbon-intensive value chains.\(^3\) State ownership has given the government significant capacity to implement low-carbon policies, including for instance the rapid scale-up of renewable energy in recent years. SOEs will remain protagonists in China’s transition to carbon neutrality. Adopting carbon accounting and monitoring systems together with enhanced disclosure, including publication of SOE-specific climate objectives and performance as part of the SOE

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sector annual reporting, would help inform SOE corporate management and facilitate monitoring and oversight. At the same time, deepening reforms to expose SOEs to market discipline and competition—in line with China’s own stated reform objectives—would help ensure emission reduction is achieved in an efficient manner. Competitive and open markets would create powerful incentives to enhance productivity, including in the use of energy and other carbon-intensive inputs while stimulating innovation and adaption of new technologies. Strengthened corporate restructuring and insolvency frameworks would also be important to facilitate market-based exit of nonviable firms and reduce excess capacity, including in high-emitting sectors.

- **Foster market-driven green finance.** While China’s green finance markets are growing rapidly, green assets still account for only a fraction of China’s financial market, with green loans and bonds making up about 8 percent and 1 percent, respectively, of the total. Green equity markets, especially for early-stage risk capital necessary to spur innovation, remain shallow. At the same time, climate risks are not properly priced in and play a limited role in asset allocation. A robust green financial market infrastructure, including standards and carbon accounting and disclosure requirements, would help catalyze the development of green finance, complemented by steps to integrate climate considerations into financial regulation and supervision. Broader financial sector reforms, particularly phasing out implicit state guarantees in financing that continue to favor the state sector, could accelerate capital reallocation to productive low-carbon investments and support the shift to a more innovation-driven, private sector-led growth.

- **Create an effective innovation ecosystem by correcting market and governance failures in innovation and early-stage technology diffusion.** Public R&D support is necessary to help resolve multiple market failures. But implementation of these policies is delicate, and public resources must be spent well to have the desired impacts. Interventions should be based on a clear understanding of their efficacy and relative cost-effectiveness. China has an extensive system of R&D support, including public guidance funds—state investment vehicles to provide equity and debt financing to enterprises—as well as other forms of demand-side subsidies to encourage shifts in consumer behavior. Enhancing the efficiency and efficacy of public R&D support will require complementary reforms to open the innovation system and encourage market entry and competition on a level playing field between private—domestic and foreign—firms and SOEs.

- **Reforming trade and investment policies to encourage low carbon production and consumption.** Analysis for this report demonstrates that China’s Non-Tariff Barriers (NTBs) and import tariffs are on average higher on lower-carbon products, particularly in the case of NTBs. This is estimated to result in an implicit subsidy on imports of high-carbon products equivalent to around $US68 per ton of CO\textsubscript{2}. The government has already announced planned tariff reforms to reduce the incentive to import high-carbon goods. NTBs could also be reviewed to identify and rationalize policy distortions that benefit high-carbon product groups or negatively affect low-carbon supply chains.

**Policy Package 5: Manage transition risks to ensure a just transition**

Ensuring a just transition needs to be a central priority in the decarbonization strategy, with policies to facilitate the labor market transition and targeted support to areas with concentrated losses. Impact simulations carried out for this report suggest that job gains are generally predicted to outweigh job losses but are likely to occur in different sectors, occupations, and regions. The results suggest an employment decline of around 1 to 2 million workers by 2030 in the coal industry, which is the most affected. Job losses are in largely male-dominated, lower-skilled occupations and in China’s central or western provinces (Figure O.7). On the other hand, job gains are predicted to be in higher-skilled industries that are more likely to be in China’s coastal cities.\(^4\)

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\(^4\) Della Vigna et al. (2021).
• Enhance labor market flexibility and social safety nets to enable a more seamless labor market adjustment. Reducing barriers to labor mobility, reforms to the hukou (household registration) system, and the portability of social benefits could help lower the adjustment costs of the transition. Tailored social safety nets, including temporary income support, could also help cushion negative employment shocks and encourage workers to remain in the labor market. Effective active labor market policies—re-skilling, job matching, and transition support—will also be needed to buffer labor market impacts.

• Provide more targeted assistance that goes beyond social safety nets, to groups that will experience concentrated losses from the low-carbon transition. Even though direct coal-related jobs account for a very small share of China’s total, they are heavily concentrated. Three provinces alone account for two-thirds of direct coal jobs. The economies of these provinces are also undiversified and highly dependent on coal for fiscal revenues. It will be important to assist workers to move to new opportunities and to provide other forms of growth, employment, and revenues in affected communities, using targeted place-based support and investment focusing on economic growth, diversification, and regeneration in coal regions.

Figure O.7. Job Losses Will Disproportionately Affect Lower-Skilled Men, Working Inland, Whereas Job Gains Are More Likely to Be Urban, Skilled Jobs in Coastal Regions

Distribution of jobs lost and gained, holding job characteristics fixed.

Policy Package 6: Foster global climate action

Beyond China’s direct contribution to meeting global emissions reduction targets, its large domestic market size, industrial prowess, and growing trade and financial linkages, especially with developing countries, create additional opportunities to foster climate action. To maximize its impacts on global climate goals, domestic policy shifts will need to be complemented by consistent external policies to ensure climate-friendly trade and investment links with the rest of the world. The recent announcement to not build new coal fired power plants is an important step in this direction.

• Create stricter rules for outward foreign finance: Encourage Chinese lenders, including policy banks (China Development Bank and China Exim) to adopt clean financing principles (the “Equator Principles”) and to phase out the financing of coal and other carbon-intensive infrastructure. Climate-related information disclosure and guidance on standards would also be important.

5 He et al. (2020).
• Assist emerging economies with low-carbon projects: China could take steps to encourage the emerging economies in which it finances infrastructure to opt for lower-carbon projects. Technical assistance using China’s own experience in ramping up renewable energy could help other countries forge a viable lower-carbon path and deepen markets for low-carbon technologies.

From Analysis to Action

To kick-start the transition to more resilient, carbon-neutral development, we conclude with the following priorities for action during the next five years: The proposed policy measures combine economy-wide and sector-specific reforms in the key emitting sectors. Several of them are good for the climate and for development. For example, reforms to ensure the development of more compact and livable cities would make China’s cities more resilient and reduce their carbon footprint while boosting productivity gains from agglomeration. Similarly, structural reforms to enhance competition, provide a more decisive role to market forces in resource allocation and rebalance the economy from industry to services would contribute to achieving both climate and growth objectives. Reforms should be sequenced to take advantage first of no-regret steps and lower-hanging fruit—for example, the availability of low-cost renewable technologies in the power sector. Some of the measures, like the accelerated rollout of renewable energy generation capacity, contribute to speedy reductions in emissions. Others—for example, refining China’s ETS or investing in low-carbon research and development—may not cause large immediate gains but could establish important foundations for deep decarbonization in the long run. Together, these measures constitute critical first steps that China could take over the next five years. Given the uncertainties involved, policies and their impacts will have to be monitored and adapted over time.

Table O.3. Short-term (next 5 years) priorities

<table>
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<tr>
<th>Rationale</th>
<th>Policy Options</th>
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<tbody>
<tr>
<td>1. Define the trajectory to carbon peaking and deliver clear signals to firms</td>
<td>China has made long-term commitments, but short-term emission targets remain ambiguous. • Provide clear forward guidance by setting annual mass-based emissions caps over the next decade, supported by a consistent carbon accounting framework for firms, provinces, and cities.</td>
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<tr>
<td>2. Accelerate the power sector transition with market reforms and investments in renewables</td>
<td>The sector is highly reliant on coal, and it occupies the largest share of total emissions. Green energy technologies are increasingly available and affordable. The demand for electrification in downstream sectors (transport, industry) is rising. • Increase, by 2030, solar and wind power generation capacity to 1200 GW to 1,700 GW, supported by additional energy storage of 200 GW and more flexible electricity grid. • Adopt international best practice in system planning, reliability regulations, and variable renewable energy (VRE) generation forecast and dispatch to enable phasing down of coal use. • Expedite electricity market reforms, including pricing reforms, development of ancillary service and capacity markets, and interprovincial power trade. • Promote demand management measures, including energy efficiency, distributed renewable energy, and demand response programs.</td>
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<td>3. Decarbonize key energy demand sectors—industry and transport</td>
<td>Emissions from transport and industry are increasing. There is potential to switch to clean energy sources, including electrification, efficiency improvement, and demand management. • Adopt macroeconomic policies to support rebalancing from industry and investment-led to services and consumption driven growth. • Set clear and ambitious emissions reduction targets and technology standards in the cement and iron and steel industries.</td>
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### Rationale | Policy Options
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• Accelerate electrification of the private and commercial fleets, moving away from focus on public buses, providing tax incentives toward price parity, nonmonetary incentives, and adequate charging infrastructure (in conjunction with the low carbon energy transition to decarbonize power supply). |  
• Incentivize transport users to improve fuel and operating efficiency through pricing and regulations on vehicle and fuel standards. |  
• Promote modal shifts to public mass transit and low-carbon freight modes (railways and waterways) through modal integration and pricing incentives. |  

### 4. Enhance climate resilience and adaptation in rural landscapes and urban areas
The land-use sector can be harnessed to increase resilience, and it can become a net carbon sink providing opportunities to offset hard-to-abate emissions in other sectors. |  
• Develop an adaptation policy framework for agriculture, increase the use of nature-based solutions, and use scientific and meteorological information to inform water use and water resources planning. |  
• Increase the profitability of investments in NbS by accelerating forestry sector reform, reorienting eco-compensation, and leveraging carbon offset markets. |  
• Repurpose public sector support to agriculture to support low-carbon land use and promote the reuse of agricultural waste. |  
• Strengthen policy framework on urban land-use and spatial planning, to discourage sprawl. |  
• Strengthen standards and provide fiscal incentives for energy conservation and emissions reduction in the building sector. |  
• Strengthen interinstitutional collaboration and vulnerability data access to households, firms, and local governments, and develop an adaptation effectiveness evaluation framework. |  

### 5. Harness markets to drive cost-effective economy-wide abatement and innovation
Economy-wide climate policies are necessary to internalize both the negative externality of carbon emissions and the positive externalities from innovation. |  
• Expand the use of carbon pricing mechanisms, including the ETS, with a focus on (i) building market infrastructure, (ii) unifying performance benchmarks, and (iii) introducing permit auctioning as the foundation for a gradual transition toward an effective cap and trade system with an absolute emissions cap. |  
• Enhance competition between SOEs and non-SOEs to allow market forces to drive allocation of capital and R&D resources. |  
• Revise nontariff trade barriers to eliminate incentives to trade in high-carbon products. |  
• Reform R&D support for low-carbon technologies, moving from quantity to quality of research and patenting. |  
• Harness the financial sector by establishing corporate emissions accounting systems, mandating climate-related financial disclosures, and using blended finance to favor innovation. |  

### 6. Mitigate the social costs of the transition and prepare the labor force for the low-carbon economy
The low-carbon transition will have distributional implications. Households will also be affected by rising energy prices and by changes in the labor market. |  
• Improve labor mobility through hukou reform and active labor market programs. |  
• Provide targeted assistance to communities that will experience concentrated job losses. |  
• Revisit government skills development strategies and systems and work with schools, training institutions, employers, and workers to incorporate green skills into the relevant programs. |
<table>
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<td><strong>7. Foster global climate action</strong></td>
<td>• Encourage Chinese lenders, including policy banks—China Development Bank and China Exim—to adopt clean financing principles (&quot;the Equator principles&quot;), and phase out financing of coal and other carbon-intensive infrastructure.</td>
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<td>With China being the largest source of infrastructure financing in low-income economies, adopting climate-friendly investment practices would amplify global impact.</td>
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