



## Commentary

Peaking China's CO<sub>2</sub> emissions by sectoral actions**It is essential- and feasible-to peak carbon dioxide emissions from the world's top emitter, China, by taking action in key sectors.**

Cutting down carbon dioxide (CO<sub>2</sub>) emissions from China, the world's top carbon emitter at present, is crucial for global climate mitigation. In its revised Nationally Determined Contribution to the Paris Agreement, China has pledged to achieve carbon neutrality before 2060, with the first step to peak its carbon emissions before 2030. Yet, China's economy is still in the stage of rapid growth, which would pose colossal challenges to peaking CO<sub>2</sub> emissions in the 2020s. Therefore, a rapid and far-reaching clean transition of the economy in the world's largest developing country is imminent.

Fuel combustion and industrial processes in China together emitted 11.5 billion tons of CO<sub>2</sub> in 2020, equivalent to ~30% of the world's total [1]. CO<sub>2</sub> directly released by the power, manufacturing, transportation, and building sectors contributed 40%, 44%, 9%, and 6% of the national total. Splitting the manufacturing sector shows that the iron and steel, cement, aluminum, petrochemical, and coal chemical industries are major emission industries regarding total production-related emissions. Hence, tailored measures targeting those eight major sectors and industries are key to peaking CO<sub>2</sub> emissions in China.

Here, eight sectoral carbon emission projection models, incorporating detailed energy classifications and technology options, were developed based on inputs from over 100 sector specialists and policymakers across their respective domains in China [1,2]. With that, we propose essential actions for cutting CO<sub>2</sub> emissions from key sectors and design a roadmap that schedules staggered peaking timelines for different sectors to support China's ambitious but challenging carbon removal strategies.

**1. Green the manufacturing sector**

China is a renowned world factory. The outputs of more than 40% of the major industrial products from China rank first in the world. For example, in 2023, China produced 1.0 billion tons of crude steel and 2.0 billion tons of cement, which are greater than all other countries combined. With indirect emissions included, manufacturing-related CO<sub>2</sub> emissions account for around 2/3 of the national total and, hence, to a large extent, direct the trends in China's total emissions [3]. Specifically, it is imperative for the manufacturing sector to swiftly peak the emissions, freeing up spaces for potential increases in emissions from the power and transportation sectors, thereby mitigating a steep surge in China's overall emissions by the designated peaking time.

**Eliminate old facilities.** Heavy industries have long been the

booster of the economy in many regions. This inertia keeps influencing many local authorities. Yet, with the new carbon pledge, it is inevitable to change the development ideology to avoid pursuing a future on a high-carbon track. A key is to reinforce the capacity replacement policy, which mandates the removal of equivalent or greater industrial production capacity when new facilities are built. That is, close outdated facilities and then build advanced new facilities with smaller production capacity.

**Increase efficiency.** Although China's industrial sector has undergone a fundamental transformation in the past decades, a large potential still exists in efficiency increment [4]. For example, the 2022 average energy consumption per ton of cement production in China (126 kgce ton<sup>-1</sup>) was equivalent to the 2000 level in Japan [5]. The standard of energy intensity for heavy industries could further be tightened to promote the implementation of advanced energy-saving technologies, such as waste heat recovery technologies for steel plants and aluminum electrolysis cells.

**Recycle resources.** Recycling wasted resources would effectively reduce the energy consumption and environmental footprint of production processes. The resource recycling rate in China is generally at a low level. For example, the steel recycling rate is about 22% in China, compared with ~70% in the United States. According to our analysis, increasing this recycling rate to 35% by 2030 would reduce China's CO<sub>2</sub> emissions by ~130 million tons. A similar amount of CO<sub>2</sub> abatements could be achieved by increasing the aluminum recycling rate from ~20% to 30%.

**2. Renew the power sector**

The power sector is China's largest carbon-emitting source. More importantly, these emissions are expected to continue increasing in the 2020s due to demand expansion. Thus, it is urgently necessary to expand the deployment of renewable energy, ensuring that most of the additional electricity demand is fed by clean energy.

**Demand pressure.** Based on China's strategic planning, the country's energy consumption would increase by ~20% in the 2020s, reaching a level of ~6 billion tons of coal equivalent [6]. Electricity is expected to dominate the increment due to the combined effects of improvements in citizens' living standards, the development of energy-intensive high-tech industries (such as cloud computing), and the increasing electrification levels in widespread sectors. To achieve economy-environment synergy, cleaning the electricity sources by replacing coal with renewables would be necessary.

**Expand non-fossil.** Our analysis suggested that it is vital to keep installing more renewables at an accelerated pace, ensuring that

the total installed capacity of wind and solar power reaches 1.6 TW by 2030. This is highly possible given that China is in a leading position in the installed capacity of renewable energy. For example, the country's installed capacity of wind and solar power both passed 0.3 TW by the end of 2021, accounting for more than 1/3 of the global total. In the same year, the country's installed non-fossil capacity surpassed coal power (i.e., 47.0% vs. 46.7%) for the first time [7]. The expansion of renewable energy could be the most effective measure to reduce China's CO<sub>2</sub> emissions in the next decade. Hence, the flexibility transformation of coal-fired power plants and the infrastructure construction are also important to ensure grid stability in the expected high renewable energy penetration scenario.

### 3. Decarbonize the transportation sector

In 2020, China's transportation sector emitted ~1.1 billion tons of CO<sub>2</sub> [3]. Economic growth will continue driving the demand for passenger and freight transport, as can be concluded from the trends in the United States and the European Union. If the transportation structure were not optimized, this growing trend would likely propel a similar trend in the associated CO<sub>2</sub> emissions.

**Promote electric vehicles.** China is the largest market and producer of electric vehicles (EVs). Yet, far more EVs are needed. The State Council has set a target to reach a 40% market share for EV sales by 2030, equivalent to an annual sale of ~12 million EVs based on current auto sales. This target is likely to be achieved far ahead of the plan, as the sales of EVs in 2023 already accounted for more than 30% of the total sales in China. In addition, as the competitiveness of electric passenger vehicles continues to grow rapidly, it is essential to shift the policy focus toward promoting electric commercial vehicles in the future.

**Remove old cars.** Fossil fuel-powered vehicles currently dominate the vehicle fleet in China; thus, it is vital to improve the overall energy efficiency of the fleet. Less-efficient old cars and trucks could be gradually eliminated, as China has done in the past decade, which has been demonstrated to improve urban air quality and reduce CO<sub>2</sub> emissions substantially. In addition, efforts could be made to reduce the carbon emission intensity of newly produced passenger vehicles and commercial vehicles by 25% and 20%, respectively, from 2020 to 2030. With these efforts, petroleum consumption for on-road transportation in China would peak before 2030.

**Optimize cargo structure.** China's freight, especially for bulk commodities such as steel and cement, heavily relies on road transport by diesel-powered trucks. The carbon intensity of road freight is orders of magnitude higher than that of rail and waterborne freight. Thence, the modal shift from road to rail and waterborne freight is essential for long-distance transportation of bulk commodities [8]. Regarding short-distance transportation, substituting diesel-powered heavy-duty trucks with electric trucks has been proven feasible. Examples include the electric dump truck fleet in Shenzhen and many other cities in China.

### 4. Renovate the building sector

Total CO<sub>2</sub> emissions associated with residential activities (~2.2 billion tons in 2020) [3], including direct and indirect energy use, have been growing along with the increased income of Chinese citizens. Considering the growing demand, improving energy

efficiency and reducing solid fuel use are the two keys to cutting emissions in this sector.

**Save energy.** Energy saving in the building sector requires constructing new buildings with high energy efficiency and renovating old buildings. Standards of energy efficiency for new buildings could be tightened. Renovation of residential and public buildings regarding energy efficiency improvements would also be accelerated, potentially increasing the energy-saving effect for old residential buildings by 50% by 2035.

**Swap fuels.** The clean heating policy in northern China, which substitutes coal with clean energy, such as electricity and natural gas, has effectively improved air quality and reduced CO<sub>2</sub> emissions. To build upon this success, regions covered by this policy could be further expanded, with subsidies kept in place, gradually abandoning all coal use in rural areas in northern China.

Decisive, affirmative, and vigorous actions for all sectors are urgently needed for China to peak its CO<sub>2</sub> emissions. Moreover, the day has come for a thorough, clean transition in China. No days could be wasted as the country has only 36 years to cut ~10 billion tons of CO<sub>2</sub> emissions before carbon neutrality.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Yixuan Zheng, Bofeng Cai, Yu Lei, Gang Yan\*

State Environmental Protection Key Laboratory of Environmental Pollution and Greenhouse Gases Co-control, Chinese Academy of Environmental Planning, Beijing, 100041, China

\* Corresponding author.

E-mail address: [yangang@caep.org.cn](mailto:yangang@caep.org.cn) (G. Yan).

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