China Oil Consumption Cap Plan and Policy Research Project

INSTITUTE OF ENERGY, PEKING UNIVERSITY

GREEN AND LOW CARBON DEVELOPMENT OF THE PLASTICS INDUSTRY IN CHINA

EXECUTIVE SUMMARY

北京大学能源研究院
INSTITUTE OF ENERGY

November 2022

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The Institute of Energy, Peking University is an independent energy think tank under Peking University. The Institute focuses on strategic policy research, cutting-edge technology research and development, education and training, international exchange and cooperation in the field of energy, and strives to become a top energy think tank.Taking advantage of Peking University's strong academic foundation and a wide array of disciplines, the outstanding faculty members from inside and outside the university, the convening power in education and research, the Institute works with global partners to provide smart solutions for sustainable energy transition.

CLIMATE CHANGE AND ENERGY TRANSITION PROGRAM (CCETP)

The Institute of Energy, Peking University launched the Climate Change and Energy Transition Program in March 2021, aiming to help China address climate change and promote energy transition to peak its carbon emissions by 2030 and achieve carbon neutrality by 2060. The program provides policy recommendations and support to the Chinese government by setting science-based ambitious goals and formulating clear roadmaps and effective action plans.

The program encourages China's energy industry to be safer, greener, and more efficient, and helps China reduce and ultimately phase out the use of fossil fuels. The research areas of the program include the macro analysis of the coordinated development of energy, environment, economy and society, as well as the following:

- Fossil fuel consumption cap;
- Innovation in energy technologies;
- The power sector's transition to a system dominated by renewable energies;
- Promotion of electrification;
- Low-carbon and green development of energy-intensive sectors;
- Sustainable transportation;
- Demonstration and promotion of regional, provincial, and municipal carbon-neutral models;
- Reduction of dispersed coal and plastic consumption;
- Carbon Neutrality, carbon sink, carbon market;
- Energy justice and just transition, etc.

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I. The overview of China's plastics industry

Plastics began to be mass-produced in 1950. Thanks to their light, durable and useful attributes, the plastics industry quickly became the largest user of petrochemical products. Today, the majority of the production capacity of China's petrochemical industry is used to produce the basic raw materials for plastics: ethylene and propylene. Between 2016 and 2020, 2.2 billion tons of plastics were produced worldwide[1]. According to the Ellen MacArthur Foundation, without actions to control plastic use, the global production of plastic materials, compared with 2014 levels, is expected to double and reach 600 million tons by 2035. The annual plastic production will almost quadruple to 1.13 billion tons by 2050[2].

China is the world's largest producer and consumer of plastics as well as the most active player in the global trade of plastics. Between 1950 and 2010, China's primary plastic production grew exponentially. Although the trend has slowed down since 2010, China's annual output of primary plastics still reached a record of more than 100 million tons that year, accounting for 28% of the world's total. China's apparent consumption of plastics was approximately 130.5 million tons, including 40.63 million tons of imports, with an external dependency of 25.5%[2]. Over the past 20 years, despite an overall decline in the five-year compound annual growth rate (CAGR-5), China's plastic consumption was much higher than the global level. Polyethylene (PE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET) are the main feedstocks for plastic production, accounting for approximately 75% of China's consumption, most of which are used in packaging and construction industries[2].

In 2020, China produced 76.03 million tons of plastic products, which are the mid- and downstream products of the plastics industry[2]. A significant portion of them is used as packaging and construction materials. Packaging plastics are mostly in single-use and will be thrown away after use, constituting the main source of plastic waste. Their average lifecycle is less than two years from manufacture to disposal, resulting in a notoriously high carbon footprint.

In 2020, about 40% of domestically consumed plastic products remained in the economic system, and around 50% are landfilled, discarded in nature, or incinerated resulting in greenhouse gas emissions. Only 10% is effectively recycled. According to our calculation in this report, of 84 million tons of plastic waste generated in 2020, 5300 tons were incinerated, with the remaining portion either landfilled or left untreated.

China's main imported plastic feedstocks are polyethylene (PE), polypropylene (PP) and polystyrene (PS), accounting for 64.7% of China's total synthetic resin imports in 2020. The main export is polyoxymethylene (POM), which accounted for 45.8% of the total trade of resin in primary form[3]. Polyethylene (PE), polypropylene (PP), and polystyrene (PS) are normally used in the manufacture of disposable consumer plastics and represent a sizeable share, reflecting the need for the optimization of the industry's value chain. The types of plastics imported and exported by China show that the demand for packaging materials is a major driver for trade. At present, the recycling rate of packaging plastics, most of which are single-use, in China is low. Reducing unnecessary use and improving the recycling rate will promote China's high-quality trade in plastics.

Ninety-nine percent of raw materials for global plastic production are fossil based, and the plastics industry consumes 8%-9% of global oil each year[4]. Plastics will be the biggest driver of future oil demand growth, as demand for fossil fuels in the transportation sector will decline. UNEP predicts that under business-as-usual circumstances, global plastics production will consume 20% of oil supply by 2050, more than a quarter of which will be single-use plastic products. Another study also predicts that by 2050, GHG emissions from plastics could account for 10-13% of the carbon budget for the global

1 Plastic Europe.Plastics–the Facts 2019〔R〕.https://www.plasticseurope.org/.2019 & https://www.statista.com

2 Data is collected from various official sources, including《China Plastics Industry Yearbook, 2021》

3 China Customs Import and Export Data

4 Nielsen, T. D.; Hasselbalch, J.; Holmberg, K.; Stripple, J. 2019. Politics and the Plastic Crisis: A Review throughout the Plastic Life Cycle[J/OL]. Wiley Interdisciplinary Reviews: Energy and Environment 9(1) . DOI: 10.1002/wene.360.

1.5-degree temperature control scenario and from 2015 to 2050, GHG emissions from plastic production will increase by nearly 400%[5].

An average of 0.90 tons of petroleum is needed to produce one ton of general-purpose plastics (primary form) in China. According to our study, considering the full life cycle of plastic production, usage and disposal management in China, GHG emissions caused by plastic use is approximately 560 million tons, about 5% of the total amount produced in China, in 2020. As one of the most important downstream products of the petrochemical industry, the low-carbon and carbon-neutral development of plastics will generate both challenges and opportunities. China's chemical industry will undergo a significant transformation towards China's "3060" goal: it will not only have a manufacturing function but will also play a role in resource recycling and a circular economy.

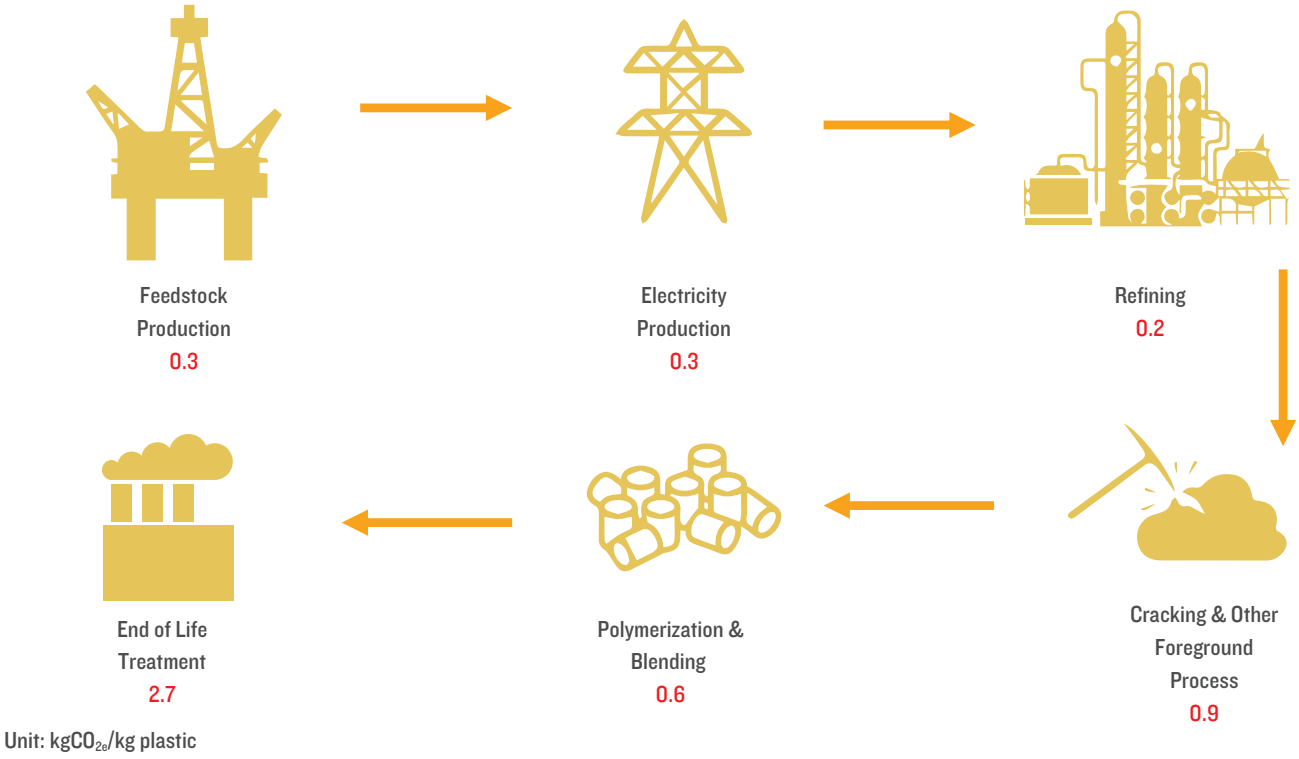
2. Forecast of GHG emission across the full life cycle of China's plastics industry by 2060

So far, no concrete action plan has been introduced for the plastics industry in response to China's "3060" commitment. Under China's "1+N" policy framework, the plastics industry is developing a roadmap, which is reflected in the actions taken by the relevant authorities as set forth in the 14th Five-Year Plan for the petrochemical industry. In this report, we conducted an analysis of full life cycle GHG emissions for China's plastics industry and made forecasts under the Business-as-usual scenario for the 2020-2060 period. It also examines its impact on China's "double carbon" policy, with preliminary results.

Plastics generate GHG emissions throughout their life cycle. The amount of carbon emitted per unit of plastic is defined as carbon intensity. This report has developed a simplified model to estimate the GHG emissions from China's plastics industry up to 2060, with the calculated average carbon intensity of 5.2 tons of CO_{2e} /ton of plastic.

5 CIEL(Center for International Environmental Law).Plastic & Climate:The Hidden Costs of a Plastic Planet〔R/OL〕.https://www.ciel.org/plasticandclimate. 2019

Figure I: Carbon intensity of "Oil-based" plastic production (5.2 tons of CO_{2e} /ton of plastic) Note1



Note I: In China, the raw material used to manufacture plastic resin are made of 85% oil, 10%coal and 5% natural gas. The calculated average carbon intensity for one kilogram plastic production in China is 5.2 tons of CO_{2e}.
Data source: Material Economics, 2019, Exhibit 3.3

This study predicts the production of plastics according to historical data and industry trends. Based on the estimated carbon intensity, the GHG emissions of plastics on the manufacturing side can be worked out by multiplying the amount of production. In parallel with this, we conducted a mass balance calculation for the plastics system, including amounts going through recycling, landfill, and incineration, thereby obtaining the GHG emissions caused by plastic treatment at the end of their lifecycle, which is another major point source.

The major assumptions of the model are as the following:

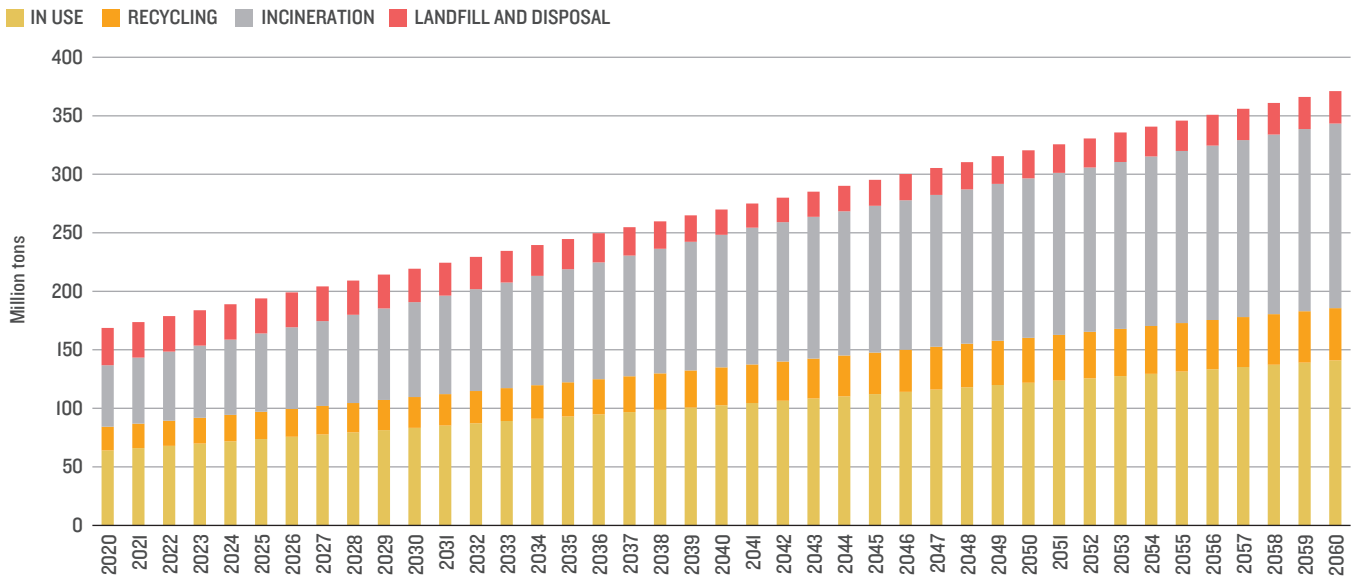
- The report predicts the production of packaging plastics based on the flow of plastics to different applications. To simulate the carbon footprint of single-use plastics, the report assumes that all plastics in the packaging industry are single-use plastics.
- For the investigated period (2020 – 2060), an average annual growth rate of plastic demand of 3% is assumed for the business-as-usual scenario, based on the data from other references and current Chinese policies. (The average annual growth rate of the number of primary forms from 2016 to 2020 is 6.5%.)
- The boundary conditions of the model are plastics produced and used in China only, and the collected production data are based on the production capacities of feedstocks instead of production rates.
- 100% of single-use plastics and 20% of durable plastics are considered to become plastic waste.
- Predictions of China's domestic waste incineration rates up to 2060 are listed as follows:

Prediction of domestic incineration rate from 2020 to 2060

Year	2020	2021	2025	2030	2035	2040	2045	2060
Incineration rate (%)	62.3	65	70	75	80	85	85	85

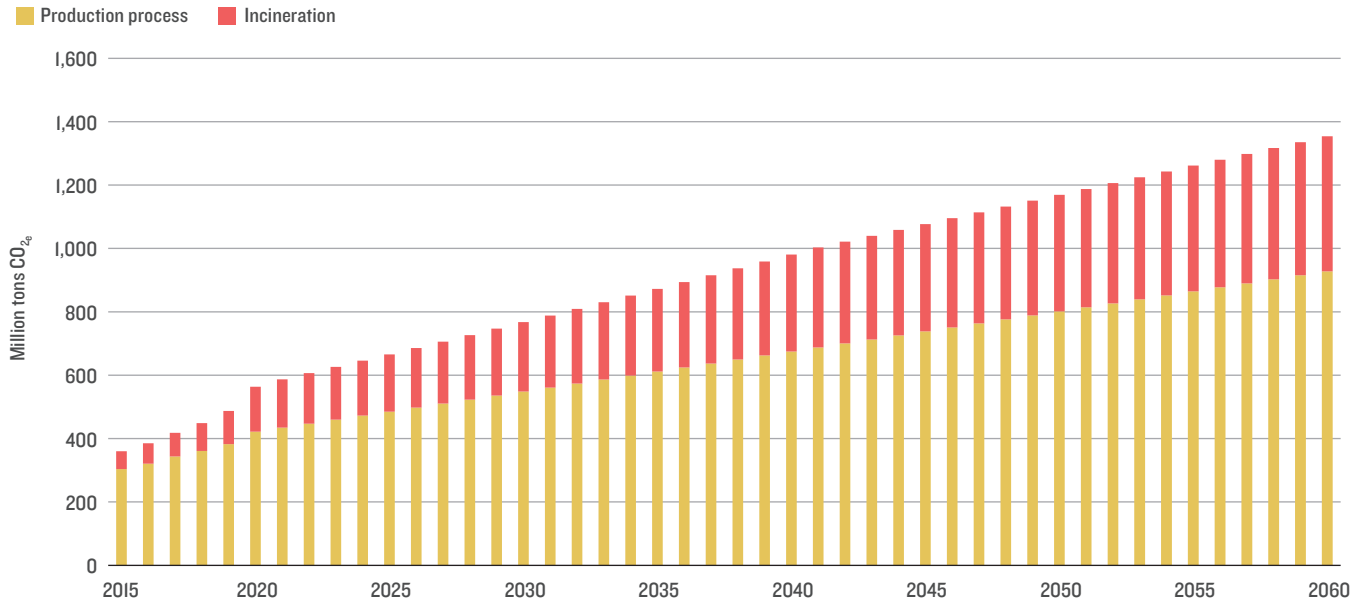
If 10% of plastics (relative to plastic production) enters the recycling system, then only 40% of the plastics will be kept in use in the system. The figure below illustrates the mass balance of plastics under the business-as-usual scenario, including material retention, recycling, incineration, landfill, and leakage. Under the BAU scenario, assuming the recycling rate is stabilized at 10% (relative to virgin plastic production), 50% of plastic waste will go to waste, the plastic kept in use in the system will increase from 64 million tons in 2020 to 140 million tons in 2060. Growing plastic production and demand have resulted in a significant increase in plastic waste and incineration. The incinerated amount of plastic waste will increase from 50 million tons in 2020 to 150 million tons in 2060.

Figure 2: Plastic material balance under Business-As-Usual scenario between 2020 and 2060



The carbon intensity of plastic production is 2.5 tons of CO_{2e} and that of waste plastic incineration is 2.7 tons of CO_{2e}. Under the business-as-usual scenario, the full life cycle GHG emission of plastics is estimated to be around 560 million tons in 2020, 770 million tons in 2030 and 1.17 billion tons in 2050. According to a study by Tsinghua University, these amounts respectively account for 4%, 6% and 88% of China's GHG emission allowances under the 1.5-degree temperature control scenario. Throughout the entire life cycle, GHG emissions from end-of-life treatment represent about 30% of the total emissions.

Figure 3: Forecast of full lifecycle GHG emissions of China's plastic usage up to 2060



According to the prediction of GHG emissions under the BAU scenario, the GHG emissions of plastics mainly come from the production process and end-of-life management. Reducing GHG emissions from plastic production essentially requires reducing plastic consumption, especially of single-use plastics. At the same time, it is necessary to further reduce the carbon intensity of plastic production by adopting green and low-carbon production processes and utilizing renewable energy. Reducing plastic incineration will be a powerful measure to reduce GHG emissions from end-of-life treatment. For non-recyclable plastics, the ban on incineration can also be a driving force to reduce the overuse of these types of plastics. In the long term, in view of plastic as a carbon-based product, utilization of CO_2 captured from CCUS to make plastics can be a great way to realize circular economy and help achieve China's"double carbon" goal.

3. Roadmap to decarbonize China's plastics industry

Based on our analysis of the BAU scenario, we have developed a roadmap to decarbonize China's plastics industry, with four core GHG emissions reduction plans formulated: **(1) reduction of production at source; (2) decarbonization of the production process; (3) prohibition of plastic incineration; (4) implementation of CCUS, to help China to achieve the "3060" goal.**

Under the above-mentioned four core paths, China's plastics industry can reach its GHG emissions peak by 2028 and achieve carbon neutrality by 2060, based on our model. Among the saved GHG emissions, 820 million tons (61%) would be contributed by the reduction of production at source, 290 million tons (21%) by the decarbonization of the production process, 80 million tons (6%) by the prohibition of plastic incineration and 160 million tons (12%) by the implementation of CCUS. The figure below breaks down the four core paths into seven steps and shows the contribution of each individual path.

Figure 4: Decarbonization roadmap of China's plastic industry

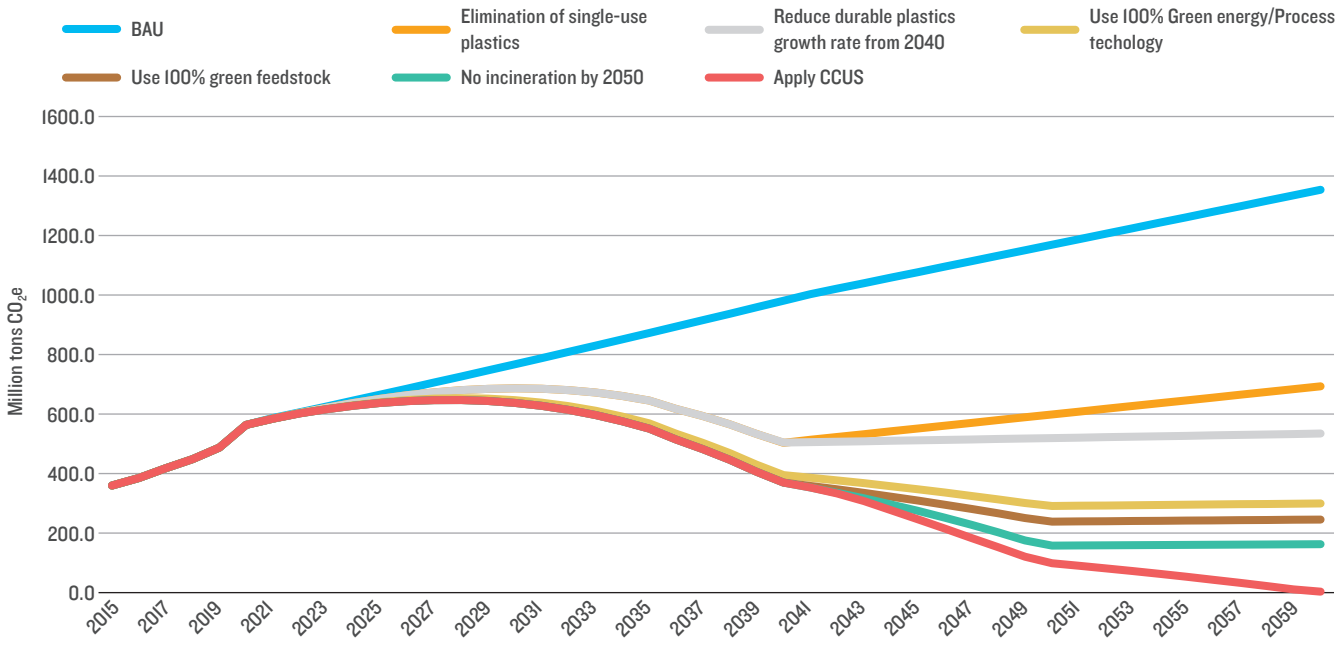
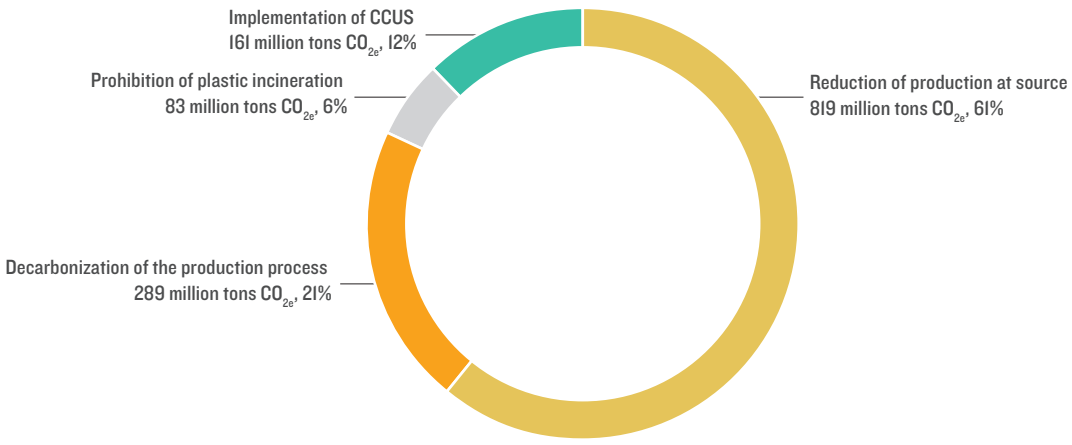


Figure 5: GHG emission reductions by Four Core Paths



Based on our analysis, we have established a timetable for decarbonizing the sector. During the 2020-2060 period, reducing plastic production, especially single-use plastics, will be critical. In the meantime, we should promote the re-fill and re-use of plastics and accelerate the creation of a comprehensive recycling system, while waste incineration should also be

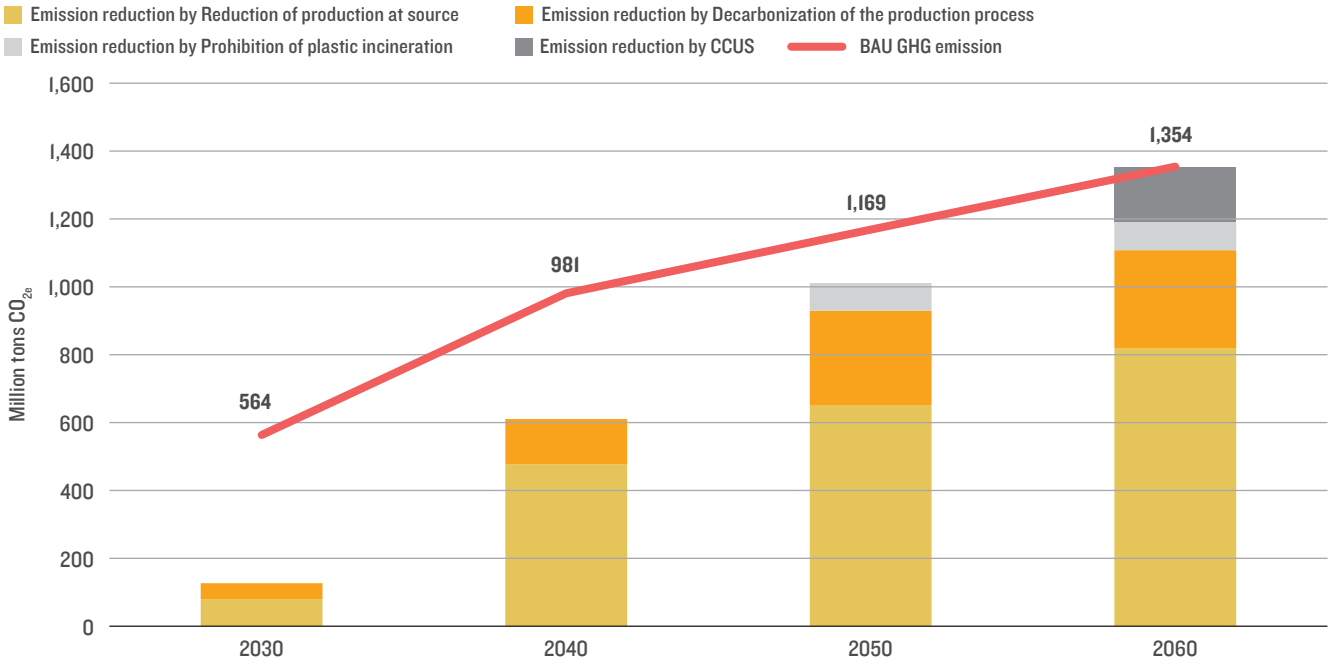
reduced. Moreover, it is necessary to promote the diversification of feedstocks, carry out structural optimization, improve the efficiency of energy consumption, deepen the electrification of the production process, and accelerate the replacement of fossil fuels with renewable resources. Reduced production at source and increased recycling will maximize the potential for emissions reduction and particularly will bring about a turning point in GHG emissions before 2030, leading to an onset of decline before 2040. Production process optimization will have the biggest impact after 2035. Reduction and ultimate elimination of plastic incineration and implementation of CCUS will dominate emission reduction efforts between 2040 and 2060, contributing to the final milestone of achieving carbon neutrality in the industry.

The challenge of realizing a carbon-neutral plastics industry is how to reduce unnecessary production, improve energy efficiency and decarbonize processes on the production side, and expand reuse and recycling, while still managing to satisfy the growing demand. To accomplish the "double carbon" goal, efforts should be made across the whole value chain of the chemical industry to save energy, reduce GHG emissions and oil consumption, and promote high-quality development as well as the transition of the industry to expand its role as a mere producer of plastics to resource recycling. By implementing the above core paths, China's plastics industry is expected to peak its GHG emissions in 2028 at about 647 million tons. By 2050, the GHG emissions will be controlled around 100 million tons, with carbon neutrality to be achieved by 2060.

4. Timetable and action plans for achieving carbon peak and carbon neutrality in China's plastic industry

Time	Milestones of the decarbonization of China's plastic industry
2030	• The recycling rate shall be increased to 34% by 2030, compared to 20% in 2020. GHG emission peaks for plastic industry in 2028.
2040	• The demand for virgin primary plastic resins will be peaked between 2030 and 2035. Completely eliminate single-use plastics.
2050	• Completely eliminate incineration. • 100% recycling is achieved. • 100% green energy and process technology. • 100% green feedstock.
2060	• Achieve carbon neutrality for the plastic industry.

Figure 6: Phased implementation priorities for 2020-2060



	2020-2030	2030-2040	2040-2060
Reduction of production at source	• Design the strategic roadmap for reducing single-use plastics. • Conduct pilot programs to implement extended producer responsibility (EPR) to enhance the development of the recycling system and circular economy.	• Establish a target for capping virgin primary plastics consumption. • Establish an index to evaluate the carbon footprint of products. • Focus on cutting-edge technology and grow the market for high-end products and reduce the export of low-end products.	• Improve the recycling sytem, including the durable plastics.
Decarbon-ization of the production process	• Improving energy efficiency benchmark and phase out production capacities which fall behind the national benchmark.	• Application of low-carbon technology, green power and green feedstock materials for plastics production.	• Increase the use of green stock in primary plastic production significantly, for example green hydrogen and insure high proportion of power from the renewable energy.

	2020-2030	2030-2040	2040-2060
Prohibition of plastic incineration	• Reduce incineration by reducing plastic production at source.	• Prohibit incineration of plastics which cannot be recycled by 2040 (recommended but not considerred in the model).	• Limit and eventually ban the incineration of plastic waste. • Strictly control pollutants' emission levels from waste incineration plants.
CCUS	• Through fiscal and taxation policies and market mechanisms, drive the breakthrough of techonology developmemt	• Implement CCUS at large scale in the petrochemical industry.	• Improve the carbon trade system for petrochemical industry. The cost of CCUS shall be significantly driven down.

Priorities of actions between 2020 and 2030:

- Design the strategic roadmap for reducing single-use plastics.
- Conduct pilot programs of extended producer responsibility (EPR) to enhance the development of recycling systems and circular economy.
- Optimize the production process, for example, by improving energy efficiency benchmark and phasing out production capacities which fall short of the national benchmark.

Priorities of actions between 2030 and 2040:

- Establish a target for capping virgin primary plastics consumption.
- Use low-carbon technology, green power, and green feedstocks in plastics production.
- Optimize the supply structure by developing a high-quality plastics market.

Priorities of actions between 2040 and 2060:

- Deeply decarbonize the petrochemical industry through fiscal and taxation policies and market mechanisms.
- Limit and eventually ban the incineration of plastic waste.
- Promote technological breakthroughs in CCUS and adopt them on a wide scale in the petrochemical industry.

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