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Institute for Global Decarbonization Progress

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Nitrous Oxide Reduction Efforts and Prospects in China

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1. Nitrous Oxide: The Third Largest Greenhouse Gas in The World

Emissions of nitrous oxide (N_2O), a major GHG, are gaining increased attention. Data from the Global Atmospheric Research Emissions Database (EDGAR) indicates that global N_2O emissions in 2023 reached approximately 2.5 billion tons of carbon dioxide equivalent (CO2e), accounting for 5% of global GHG emissions. This makes N_2O the third largest GHG after carbon dioxide and methane.[1] Although N_2O emissions are relatively lower compared to carbon dioxide, it has a strong warming effect, with a warming potential of about 273 times greater than carbon dioxide over a 100-year period—and long atmospheric lifespan of around 120 years.[2] The 2024 global N_2O budget also reveals that N_2O emissions from human activities have increased by 40% between 1980 and 2020.[3] In addition, research shows that, without additional measures, N_2O emissions are expected to rise by approximately 30% by 2050 compared to 2020.[4] Therefore, taking early action to reduce N_2O emissions is essential to mitigate climate change.

In addition to contributing to global warming, N_2O emissions significantly deplete the ozone layer, increasing human exposure to harmful radiation. While the Montreal Protocol has made substantial progress in restoring the ozone layer by regulating major ozone-depleting substances, N_2O emissions remain outside its scope. As a result, N_2O has become the primary gases depleting the ozone layer.5 The United Nations Environment Programme (UNEP) highlighted this issue in its 2022 scientific assessment of ozone depletion. The report found that N_2O emissions (using CFC-11 equivalent) from human activities between 2016 and 2020 were twice as high as global emissions of CFCs in 2020.6 Furthermore, these N_2O emissions are expected to delay the ozone layer's recovery, underscoring the need for targeted mitigation efforts.

[1] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W. E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E., & Pekar, F. (2024). GHG emissions of all world countries. Publications Office of the European Union. https://doi.org/10.2760/4002897

[2] The GWP values used in the IPCC Sixth Assessment Report are used here

[3] Tian, H., Pan, N., Thompson, R. L., Canadell, J. G., Suntharalingam, P., Regnier, P., ... & Zhu, Q. (2023). Global nitrous oxide budget 1980–2020. *Earth System Science Data Discussions*, *2023*, 1-98.

[4] Valerie Volcovici. (October 31, 2024). World will miss Paris climate target as nitrous oxide rises, report says. Reuters. https://www.reuters.com/business/environment/world-will-miss-paris-climate-target-nitrous-oxide-rises-report-says-2024-10-31/

[5] Alcamo, J., & Bouwman, L. (2013). Drawing down N_2O to protect climate and the ozone layer. United Nations Environment Programme.

[6] UNEP. (2023). Scientific Assessment of the Ozone Layer Depletion: 2022. https://ozone.unep.org/system/files/documents/Scientific-Assessment-of-Ozone-Depletion-2022.pdf

Reducing N_2O emissions can also offer additional environmental benefits, as nitrogen oxides (NOx), a common air pollutant from stationary sources, contain small amounts of N_2O. Lowering N_2O emissions not only helps with climate mitigation but also contributes to improving air quality by reducing photochemical smog and minimizing soil acidification.

2. Current Status and Trends of N_2O Emissions

2.1. Global N_2O Emissions: Human Activities Drive the Increase

While natural sources such as soil, oceans, and the atmosphere contribute to global N_2O emissions, these do not result in significant atmospheric accumulation, as natural systems can gradually balance them over time.[7] The current rise in N_2O emissions is primarily driven by human activities.

In 2019, agriculture was the largest contributor, responsible for 76% of anthropogenic N_2O emissions, followed by energy-related activities (10%), industrial processes (8%), and waste management (5%).[8]

[7] Alcamo, J., & Bouwman, L. (2013). Drawing down N_2O to protect climate and the ozone layer. United Nations Environment Programme.
[8] Climate Watch. (2019). https://www.climatewatchdata.org/

Agriculture

N_2O emissions primarily arise from agricultural land and manure management. When farmers use nitrogen-based fertilizers, N_2O is released into the soil. Additionally, manure from livestock and poultry stored or treated can also produce N_2O through natural chemical processes.

Energy activities

Emissions are mainly from the combustion of fossil fuels and biomass.

Industrial process

Major sources include the production of adipic and nitric acid. Adipic acid is primarily used in nylon and polyurethane. Nitric acid is essential for the manufacture of synthetic fertilizers, pesticides, and rubber.

Waste management

N_2O emissions mainly come from domestic sewage and industrial wastewater treatment.

2.2. China's N_2O Emissions: Agriculture and Industry Are Key Contributors

According to the Third Biennial Update Report on Climate Change of the People's Republic of China (Figure 2), China's N_2O emissions in 2018 reached 1.915 million tons, accounting for 5% of the nation's total GHG emissions (excluding LULUCF). The largest source was agriculture (943,000 tons or 49.2%), followed by industrial processes (441,000 tons or 23%), energy activities (411,000 tons or 21.5%), and waste management (119,000 tons or 6.2%).

Historical data from China's national greenhouse gas inventory reveals that N_2O emissions rose sharply by 36% from 2005 to 2014 but stabilized between 2014 and 2018 (Figure 1). However, projections indicate that without stronger policy intervention, emissions could continue to rise, potentially reaching between 620 and 790 million tons of CO_2e by 2050 (Figure 3).

Figure 1: China's N_2O emissions (10,000 tons)

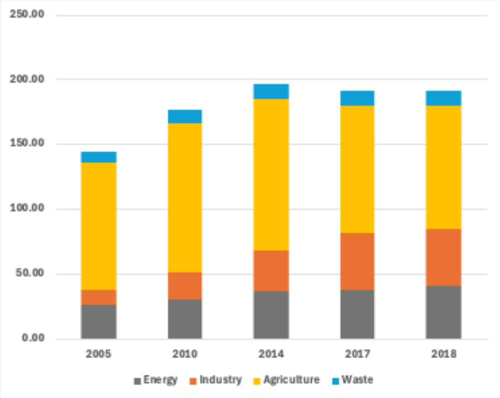
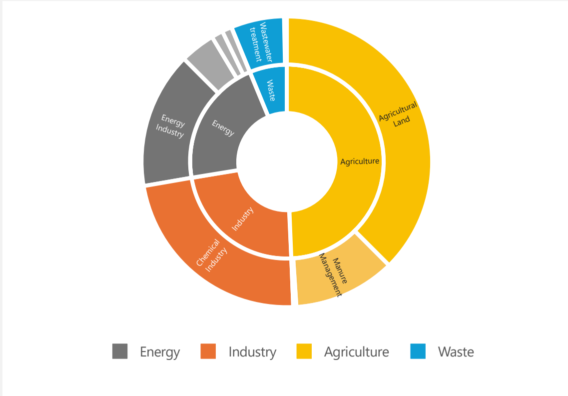
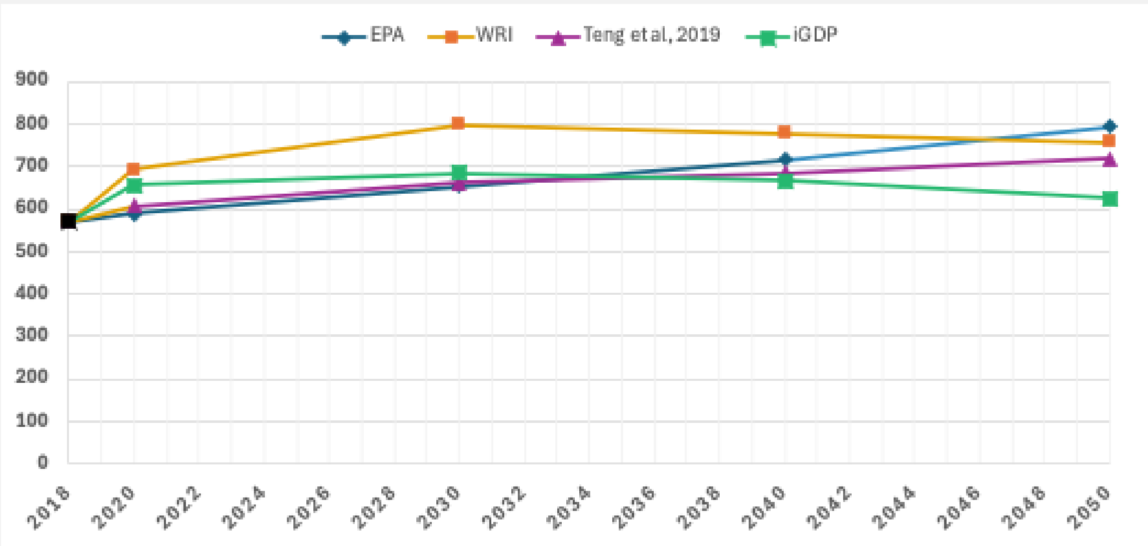


Figure 2: China's N_2O emissions by Sector (2018)



Source: National Communication on Climate Change and the Second and Third Biennial Updates of the People's Republic of China on Climate Change

Figure 1: Projected N_2O emission trends in China across different studies (MMT CO_2e, GWP=298)



Source: Teng et al, (2019),[9] WRI data from Song, R. (2019),[10] EPA data from USEPA. (2019),[11] iGDP data is based on EPS model analysis.

[9] Teng, F., Su, X., & Wang, X. (2019). Can China peak its non-CO2 GHG emissions before 2030 by implementing its nationally determined contribution? Environmental Science & Technology, 53(21), 12168–12176

[10] Song, R. (2019). Opportunities to Advance Mitigation Ambition in China: Non-CO2 Greenhouse Gas Emissions. World Resources Institute.

[11] USEPA. (2019). Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential 2015–2050. US Environmental Protection Agency.

3. Progress on N_2O Emission Reduction Policies

3.1. Progress in Global N_2O Emissions Reduction

Countries and regions are increasingly taking proactive steps to reduce N_2O emissions. In the European Union (EU), the Farm to Fork Strategy aims to enhance soil health and cut nitrogen fertilizer use by 20% by 2030, as part of the Green New Deal.[12] Australia is providing financial incentives through the Emissions Reduction Fund to encourage businesses and individuals to decrease N_2O emissions in agriculture .[13] Since 2013, the EU has included the regulation of N_2O emissions from nitric acid and adipic acid production in its carbon market.[14] Additionally, the United States recently announced that major chemical companies will aim to reduce N_2O emissions from the industrial sector by about 50% by 2025, relative to 2020 levels.[15]

International collaboration on N_2O reduction is also gaining momentum. During COP21 in 2015, Germany launched the Nitric Acid Climate Action Group (NACAG) to promote the installation of N_2O emission reduction technologies at nitric acid and urea plants globally, providing technical and financial support to participating countries. Sixteen countries, including Argentina, Indonesia, Mexico, and Thailand, have joined this initiative.[16] In 2023, Argentina began installing N_2O emission reduction devices and monitoring equipment in nitric acid production facilities with NACAG's support.[17]

The United States and Brazil also launched a research collaboration called "Fertilize 4 Life" in 2023, focusing on improving fertilizer application efficiency and reducing GHG emissions from fertilizers. This initiative is part of the Global Fertilizer Challenge initiated by the U.S.[18] Furthermore, in the 2023 Sunnylands Statement

[12] European Commision. (2020). Farm to Fork Strategy: https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf
[13] Australia Government: Emissions Reduction Fund. https://www.agriculture.gov.au/agriculture-land/farm-food-drought/climatechange/mitigation/cfi
[14] Oeko-Institut. (2021). N_2O mitigation potentials and costs in the nitric acid sector: A 2020 assessment for the Nitric Acid Climate Action Group (NACAG). Oeko-Institut.
[15] The White House. (July 23, 2024). https://www.whitehouse.gov/briefing-room/statements-releases/2024/07/23/fact-sheet-biden-harris-administration-announces-new-actions-to-detect-and-reduce-climate-super-pollutants/#:~:text=New%20Industry%20Leadership%20to%20Reduce,by%20over%2050%25%20since%202020.
[16] NACAG. Introducing Nitric Acid Climate Action Group: https://www.nitricacidaction.org/
[17] NACAG. (2023). Argentina takes further steps towards mitigating N_2O emissions in the Nitric Acid Sector. https://www.nitricacidaction.org/argentina-takes-further-steps-towards-mitigating-N₂O-emissions-in-the-nitric-acid-sector/
[18] Ibid.

on Enhancing Cooperation to Address the Climate Crisis, China and the U.S. expressed plans to collaborate on managing N_2O emissions.[19]

3.2. China's N_2O Emission Reduction Actions

While China has not yet introduced a dedicated plan for N_2O emission control, it has prioritized the mitigation of non-CO_2 GHGs, including N_2O, within its dual carbon policies. In its 2021 report, China's Achievements, New Goals and New Measures for Nationally Determined Contributions, China highlighted the importance of developing targeted N_2O reduction strategies for key industries.

In addition, sector-specific policies under the dual carbon policy framework are advancing efforts to reduce N_2O emissions. For example, the 14th Five-Year Plan for Green Agricultural Development (2021) promotes reduced chemical fertilizer use, increased efficiency, and better utilization of livestock manure. The 2022 Action Plan for Carbon Sequestration in Agriculture and Rural Areas aims to enhance nitrogen fertilizer efficiency and cut N_2O emissions. Table 1 outlines key policy measures driving N_2O mitigation efforts in China.

[19] Xinhua. (2023). China and the United States release a sunnyland statement on strengthening cooperation to address the climate crisis. http://www.news.cn/2023-11/15/c_1129976165.htm

Table 1: China's key policy actions for N_2O emission reduction

		Existing Emission Reduction Actions	Policy Sources
Targeting GHGs, including N_2O		• Strengthen the control of other GHGs such as methane, hydrofluorocarbons, and perfluorocarbons • Study and implement action plans for controlling non-carbon dioxide greenhouse gas (non-CO_2 GHGs) emissions, continue to improve the technical system for monitoring, reporting and evaluating non-CO_2 GHGs, and gradually establish and improve the statistical accounting system, policy system and management system for non-CO_2 GHGs emissions • Incorporate GHGs control into Environmental Impact Assessment (EIA) management • Strengthen the control of non-CO_2 GHGs, and study and formulate GHGs emission standards for key industries	• *Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through the Year 2035* • *Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy* • *China's Long-term Development Strategy for Low Greenhouse Gas Emissions in the Middle of this Century* • *Opinions of the CPC Central Committee and the State Council on Deepening the Battle of Pollution Prevention and Control* • *Implementation Plan for Synergy in Pollution Reduction and Carbon Reduction*
Main emission sources		**Existing Emission Reduction Actions**	**Policy Sources**
Agricultural activities	Nitrogen fertilizer use	• Reduce N_2O emissions from farmland and peak N_2O emissions from farmland by 2020 • Improve nitrogen fertilizer use efficiency and reduce nitrous oxide emissions • Promote soil testing and formulated fertilization, promote nitrogen fertilizer reduction and efficiency improvement, and organic fertilizer substitution • Subsidies for the purchase and use of organic fertilizers • Construct a long-term mechanism for replacing chemical fertilizers with organic fertilizers for fruits, vegetables, and tea • Demonstrate and promote new fertilizers such as slow-release fertilizers and water-soluble fertilizers and create a green crop-livestock integrated system.	• *13th Five-Year Plan for Controlling Greenhouse Gas Emissions,* • *National Agricultural Sustainable Development Plan (2015-2030),* • *14th Five-Year National Agricultural Green Development Plan,* • *Implementation Plan for Agricultural and Rural Carbon Emission Reduction and Sequestration,* • *Implementation Plan for Building a National Agricultural Green Development Pilot Zone and Promoting Comprehensive Green Transformation of Agricultural Modernization Demonstration Zone,* • *The 14th Five-Year Plan for Promoting Agricultural and Rural Modernization*
	Livestock and poultry manure	• Resource utilization targets of livestock and poultry manure • Provide financial subsidies for the resource utilization of livestock and poultry manure	
Industrial sector	Nitric acid and adipic acid	• Improve the production process of chemical fertilizers, adipic acid, nitric acid, and caprolactam, etc. • Control non-CO_2 GHGs such as N_2O in an orderly manner • Strengthen the monitoring, research & development of reduction alternative technologies, and standard setting for non-CO_2 GHGs, including N_2O	• *Industrial Green Development Plan (2016-2020),* • *14th Five-Year Plan for Industrial Green Development,* • *Implementation Plan for Science and Technology to Support Carbon Peak and Carbon Neutrality (2022-2030)*
Waste	Sewage treatment	• Strengthen the application of low-carbon technologies such as high-efficiency nitrogen and phosphorus removal to reduce the escape of N_2O in the denitrification process	• *Implementation Opinions on Promoting the Synergy of Sewage Treatment, Pollution Reduction, and Carbon Reduction*

Energy activities	Fossil fuel and biomass fuel combustion processes	• During the 14th Five-Year Plan period, the growth of coal consumption has been strictly and reasonably controlled, and will gradually decrease during the 15th Five-Year Plan period • Promote the substitution of coal with natural gas in industrial and agricultural applications • Promote the orderly replacement of old vehicles with new energy vehicles and the use of clean energy for non-road mobile machinery	• *Implementation Plan for Synergy in Pollution Reduction and Carbon Reduction*

4. Opportunities and Challenges for N_2O Emission Reduction in China

In the context of China's N_2O emission reduction policy, this section will identify key measures and technologies that can enhance N_2O mitigation efforts, along with an overview of their current implementation status. Since policies promoting energy transition and air quality improvements can have synergistic effects on reducing N_2O emissions within the energy sector, this section will primarily focus on the two largest sources of N_2O emissions in China: agriculture and industry.

4.1. N_2O Emission Reduction in Agriculture

4.1.1. Technologies and Practices for Mitigating Agricultural Emissions

Improving fertilizer types to enhance nitrogen use efficiency:

- Organic fertilizers: Regulating microbial activity in soil through organic fertilizers can help reduce N_2O emissions. However, challenges such as high costs, low efficiency, and insufficient infrastructure hinder widespread adoption.[20]
- Biochar application: The porous structure of biochar is conducive to microbial growth and aids in nitrogen fixation, thereby reducing soil N_2O emissions.[21]
- Slow-release fertilizer and nitrification inhibitors: Slow-release fertilizers allow for the gradual release of nitrogen, reducing nitrogen fertilizer loss, lowering usage, and cutting N_2O emissions. Nitrification inhibitors further decrease emissions by slowing the nitrification process in the soil.[22]

Optimize nitrogen fertilizer application:

- Soil testing and formulation: Fertilization tailored to soil nutrient needs helps prevent over-fertilization and improves fertilizer efficiency. Since 2005, China has promoted soil testing and formulated fertilization technologies, but there remains a gap between promoted areas and actual implementation.23
- Integrated water and fertilizer management: Drip irrigation delivers nutrients straight to the roots of crops, reducing soil conditions that favor nitrification and denitrification processes and thereby reducing N_2O emissions. China is gradually expanding the use of water-fertilizer integrated drip irrigation, especially in northern and northwestern regions.
- Precision agriculture: By using sensors to gather data on soil conditions, crop health, weather, and temperature, big data analysis can provide farmers with tailored recommendations for planting, irrigation, and fertilization, improving efficiency and reducing emissions.

[20] Xinhua. (2020). Investigation of the dilemma of organic fertilizer promotion http://www.ce.cn/cysc/sp/info/202010/13/t20201013_35881440.shtml
[21] Yan, S., Shang, Z., Deng, A., & Zhang, W. (2022). Spatiotemporal characteristics of nitrous oxide emissions from farmland in China and emission reduction pathways. Journal of Crops, 38(3), 1–8.
[22] Zou, X., Li, Y., Gao, G. Z., Wan, Y., & Shi, S. (2011). Research and analysis of major greenhouse gas emission reduction measures in China's agricultural sector. Ecology and Environmental Sciences, 20(8/9), 1348–1358.
[23] Zheng, L., Zhang, X., & Wang, B. (2018). Preliminary study on the evolution process of fertilizer and organic fertilizer subsidy policy and supporting technologies. World Environment, 4.

Optimize livestock and poultry manure management

- GHGs emissions in the process of livestock and poultry manure storage can be effectively reduced through reasonable management, including the use of solid-liquid separation in manure management, where the liquid undergoes anaerobic digestion for biogas production, while the solid is composted aerobically, and shortening the storage time of liquid manure.
- Adding excipients such as biochar and bentonite to manure storage can reduce N_2O emissions.[24] In the process of fertilizing livestock and poultry manure, N_2O emissions can also be reduced by turning the piles and forced ventilation in aerobic composting.[25]

Box 2: N_2O emission reduction practice in China's agriculture

Sinofert, with the support of the Ministry of Agriculture, has launched an intelligent fertilizer distribution service station based on intelligent fertilizer blending machines across the country since 2014. These intelligent fertilizer blending machines enable precise soil testing and fertilizer formulation. Large growers and retail farmers can both use corresponding applications linked to the internet-enabled fertilizer terminals. By entering planting information and providing soil testing samples, the fertilizer blender can quickly test the soil and send the results to the cloud.

According to the soil testing results, the cloud server calculates the planting plan, the required fertilizer formula and price, and ultimately generates a fertilizer order that is sent to the farmer's smartphone. The fertilizers provided through this smart blending system go directly from the factory to the farmers, eliminating markup costs from the distribution chain. Calculations show that the intelligent fertilizer distribution system can reduce fertilizer usage and costs by 10% to 30%, while also increasing crop yields by over 5%, resulting in a more than 10% increase in farmers' income.

[24] Lei, M., Cheng, Y., Miao, N., Zhou, J., & Chen, Z. (2019). Effects of loess and other additives on ammonia and greenhouse gas emissions during pig manure storage. Journal of Environmental Science, 39(12), 4132–4139.
[25] Zhu, Z., Dong, H., Wei, S., Ma, J., & Xue, P. (2020). Impacts of changes in livestock and poultry manure management on greenhouse gas emissions in China. Journal of Agro-Environment Science, 39(4), 743–748.

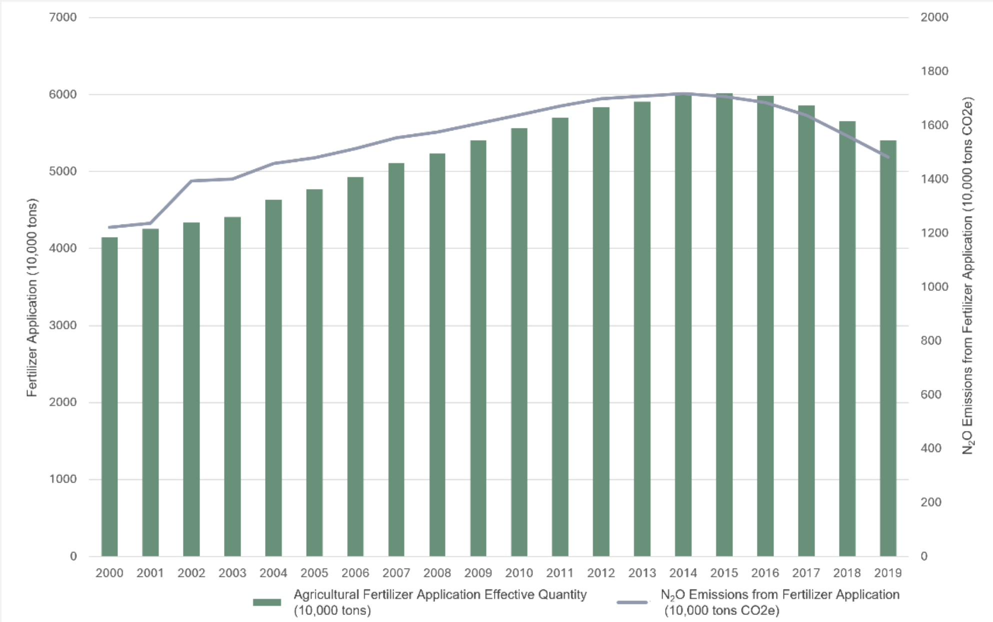
4.1.2. Challenges in Reducing N_2O Emission in Agriculture

Nitrogen fertilizer application in agricultural land is the primary source of N_2O emissions in China's agriculture. Achieving reductions in these emissions while ensuring food security and increasing agricultural production and income presents significant challenges. The main plan adopted by China is to reduce the quantity of chemical fertilizers and while increasing their efficiency, such as the zero-growth action of chemical fertilizer and pesticide use was launched in 2015. Specific actions include supporting and encouraging the use of soil testing and formulated fertilization technology, utilizing organic fertilizer resources, and demonstrating new fertilizers, such as slow-release fertilizers and water-soluble fertilizers, to reduce the use of chemical fertilizers.

As intensive policies aimed at reducing and improving fertilizer efficiency have been implemented, the application of chemical fertilizers in China has slowly declined since 2016, marking the first negative growth in fertilizer use since 1974.[26] The target for zero growth in chemical fertilizer use was also achieved three years early in 2017.[27] As shown in the figure below, China's fertilizer application was 59.84 million tons in 2016, a decrease of 380,000 tons from 2015, and it decreased to 54.03 million tons in 2019. At the same time, N_2O emissions from fertilizer use are declining. Despite the downward trend in fertilizer use, in 2021, the intensity of fertilizer application in China remained about 307 kg/ha, still more than the internationally recognized safety upper limit of 225 kg/ha.[28] In the future, achieving deep reductions in N_2O emissions to meet the carbon neutrality goal will require further exploration of diverse technologies.

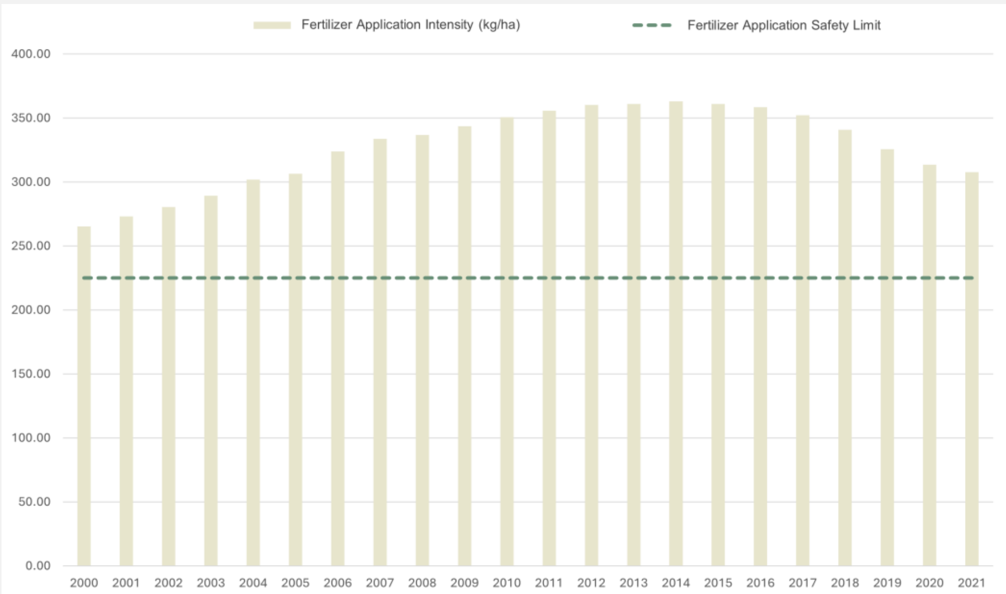
[26] Chinese Government Network. (2017). China's agricultural fertilizer consumption has achieved negative growth for the first time in 43 years. https://www.gov.cn/xinwen/2017-12/28/content_5251080.htm
[27] Xinhua. (2018). Ministry of Agriculture and Rural Affairs: The target of zero growth in the use of chemical fertilizers and pesticides has been achieved 3 years ahead of schedule. http://www.xinhuanet.com/politics/2018-04/25/c_1122739925.htm
[28] Institute for Global Decarbonization Progress. (2024). Chemical fertilizer reduction and efficiency improvement and nitrous oxide emission reduction: Observations and prospects. iGDP.

Figure 2: China's fertilizer application (10,000 tons) & fertilizer-related N_2O emissions (10,000 tons CO_2e, 2000– 2019)



Source: Agricultural fertilizer application data from the National Statistical Yearbook, fertilizer N_2O emission data from FAO

Figure 3: Fertilizer application intensity in China (kg/ha, 2000–2021)



Source: National Statistical Yearbook

4.2. N_2O Emission Reduction in Industry

The main emissions of N_2O in the industrial sector come from the production process of nitric acid and adipic acid production. About 90% of the N_2O emissions in China's chemical industry come from the production of adipic acid, followed by the emission of nitric acid production.[29] At present, the primary method for reducing N_2O emissions during the production of nitric acid and adipic acid is catalytic decomposition technology.

4.2.1. Practices and Technologies for Mitigating Industrial N_2O Emissions

- Measures to reduce N_2O emissions in the production of adipic acid can be categorized into two main types. The first one involves decomposition, which breaks down N_2O into nitrogen and oxygen. This includes thermal decomposition without catalyst, achieving around 88% decomposition, and catalytic decomposition using catalyst, achieving 95%. The second type of emission reduction measure is to purify the exhaust gas into high-purity N_2O products.[30] At present, some domestic companies have built N_2O decomposition devices in their adipic acid production units, using catalysts to treat N_2O emissions, but most companies rely on imported catalysts. In addition, a few companies have adopted technologies to extract N_2O from the tail gas.[31]
- Measures to reduce N_2O emissions in nitric acid production can be divided into primary, secondary, and tertiary control measures.[32] The primary control measures involve reducing N_2O formation by improving the ammonia oxidation catalyst, which can reduce N_2O emissions by 30%-85%, but only for new plants.[33] The secondary control measures involve placing the N_2O pyrolysis catalyst after the ammonia oxidation catalyst to decompose N_2O in the furnace, with a reduction efficiency of about 80-90%. This approach is more commonly applied due to lower

[29] Liang, M., Zhou, Z., Ren, P., Xiao, H., Hu, Z., Piao, S., ... & Yuan, W. (2024). Four decades of full-scale nitrous oxide emission inventory in China. National Science Review, 11(3), nwad285.
[30] Jiang, Y., Xu, Y., & Ai, X. (2018). Review of N_2O abatement technologies in adipic acid production. Chemical Design Letters, (9), 56–57.
[31] Zhang, C., & Yao, X. (2022). Analysis and development trend of greenhouse gas treatment in the tail temperature of adipic acid industrial production. Henan Chemical Industry, (9), 12–14.
[32] Jia, L., Xing, F., Li, C., & Jian, L. (2023). Research progress on combined removal technology of NOx and N_2O from nitric acid production tail gas. Chemical Industry and Engineering Progress, 42(7), 3770–3779.
[33] Ibid.

investment costs and simpler transformation.[34] Tertiary control measures rely on catalytic decomposition or catalytic reduction technologies to remove N_2O from the tail gas of nitric acid production, achieving a reduction efficiency of up to 95%. Compared with the secondary emission reduction, the operating cost of the tertiary emission reduction is relatively high, but because the emission reduction system is installed in the tail gas section, it has minimal impact on the production of nitric acid.[35]

Box 3: N_2O emission reduction practice in China's industry

Tianjin Luling Gas Co., Ltd. has developed the technology to recover and purify N_2O from industrial tail gas. This technology allows for the recycling of tail gas from adipic acid production to make high-purity electronic-grade N_2O gas, which is an important raw material in the production of semiconductor electronics industry. It is mainly used in the manufacturing of semiconductor chip integrated circuits, liquid crystal display panels, and photovoltaic solar panels. The first phase of the project, with a capacity of 6,000 tons, quickly reached full production after becoming operational, leading to a reduction of 6,000 tons of N_2O emissions each year. In 2017, the project received a Special Mention in the fourth annual Paulson Prize for Sustainable Cities hosted by the Paulson Institute.

4.2.2. Challenges in Reducing Industrial N_2O Emissions

At present, there are still relatively few enterprises in China's chemical industry that have installed and used N_2O emission reduction devices to produce adipic acid and nitric acid. Previously, encouraged by the Clean Development Mechanism (CDM) under the Kyoto Protocol, China's nitric acid and adipic acid enterprises have used catalytic oxidation technology to apply for N_2O emission reduction projects. For example, Liaoyang Petrochemical introduced BASF's catalytic decomposition technology to build an adipic acid tail gas emission reduction device,[36] while Henan Shenma brought in INVISTA catalyst decomposition technology for adipic acid tail gas treatment, and Anhui Huaihua Group adopted Yara's secondary catalyst to process N_2O emissions from nitric

[34] Ke, Y. (2016). Characteristics and structural design of nitrous oxide secondary emission reduction in nitric acid plants. Fertilizer Industry, 43(3), 28–32.
[35] Ke, Y., & An, M. (2014). Nitrous oxide tertiary emission reduction technology and application in nitric acid plants. Fertilizer Industry, 41(4), 42–46.
[36] Li Fei et al. (2018), Research progress and status of direct catalytic decomposition technology of nitrous oxide with nitric acid or adipic acid. Industrial Catalysis, 26(9), 6-10.

acid production.[37] However, after the EU stopped buying China's CDM projects to reduce N_2O emissions in 2013, these emission reduction devices have been operating intermittently due to a lack of additional economic incentives and policy constraints on N_2O emissions.[38]

Catalysts are a key element needed in N_2O emission reduction. Due to a late start in research and a slow process of industrial application in China, most enterprises previously relied on imported catalysts to reduce emissions.[39] In recent years, the development of carbon trading in China has prompted the domestic development of catalyst technologies.[40] For example, Chongqing Huafeng has developed a low-temperature catalytic decomposition and removal technology of N_2O in the production process of adipic acid and the constructed an industrial device with a decomposition rate of up to.[41] The N_2O emission reduction catalyst developed by Sichuan Shutai Chemical are currently undergoing trial operations in nitric acid production.[42]

[37] Chen, B., Tian, M., & Xu, R. (2023). Greenhouse gas N_2O emissions in chemical production and industrial emission reduction technologies. Environmental Engineering, 41(10), 82–90.
[38] Ibid.
[39] Li, F., et al. (2018). Research progress and status of direct catalytic decomposition technology of nitrous oxide with nitric acid or adipic acid. Industrial Catalysis, 26(9), 6–10.
[40] Chen, B., Tian, M., & Xu, R. (2023). Greenhouse gas N_2O emissions in chemical production and industrial emission reduction technologies. Environmental Engineering, 41(10), 82–90.
[41] Huafon Group. (2023). Chongqing Huafeng's green, low-carbon and high-quality development. http://www.cbcsd.org.cn/xws/hydt/20231008/104321.shtml
[42] Sichuan Shutai chemical catalyst special achievements through the appraisal: https://www.suining.gov.cn/phone/articshow/891ae2581fb54cc6b99972d54a9d55cf.html

5. Outlook for N_2O Emission Reduction Actions in China

As the world's third largest GHGs and a major non-CO_2 GHGs, N_2O still lacks sufficient policy support compared to methane and F-gases. Although there is no global strategy for overall N_2O emission reduction actions, different countries and regions are addressing major N_2O emission sources. For example, the EU carbon market regulates industrial N_2O emissions, and China and the United States have initiated collaboration on N_2O management. In addition, the number of countries that incorporate N_2O control into NDC is also increasing. According to the 2022 Nationally Determined Contributions (NDC) analysis, 89% of Parties have now included N_2O in their NDCs, an increase of 12% from the previous round.[43] However, most countries have not proposed specific N_2O emission reduction targets or measures. Only 37% of NDCs currently include CH4 and N_2O mitigation measures in agriculture, while only 9% address reductions in the industrial sector.[44]

Looking ahead, the dual role of N_2O as both a potent GHG and a contributor to ozone layer depletion has sparked growing calls from the international community to include N_2O discussions into the Montreal Protocol.[45] Strengthening international cooperation on N_2O reduction, coupled with inter-regional initiatives addressing different emission sources—such as sharing best practices and technical exchanges—will help reduce global N_2O emissions.[46] In addition, the establishment of a global funding mechanism similar to Germany's NACAG project could provide vital support for N_2O reduction in developing countries, accelerating global N_2O emission reduction action.

As a key advocate of the Paris Agreement, China has been actively engaged in global efforts to address climate change. Throughout the 14^{th} Five-Year Plan period, China's "dual carbon" strategies have increasingly prioritized non-CO_2 emissions reduction. This period has seen the implementation of several initiatives with potential for reducing N_2O emissions, such as promoting more efficient fertilizer use and

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[43] Climate and Clean Air Coalition (CCAC). (2024). Guidance on Including N_2O in Nationally Determined Contributions
[44] Ibid.
[45] Dhawan, V., Kanter, D. R., & Fajardo, R. V. (2023). Developing a global nitrous oxide reduction policy for a food-secure future and Davidson, E. A., & Winiwarter, W. (2023). Urgent abatement of industrial sources of nitrous oxide. Nature Climate Change, 13(7), 599-601.
[46] Dhawan, V., Kanter, D. R., & Fajardo, R. V. (2023). Developing a global nitrous oxide reduction policy for a food-secure future.

enhancing the resource recovery of livestock and poultry waste. However, challenges remain, particularly in agriculture and industry, including the need to advance cost-effective, innovative fertilizers and lower catalyst costs for industrial N_2O emission reductions. As a result, further policy support, including funding and capacity building for the adoption of new emission-reduction technologies, will be crucial to achieving these reductions.

Author: Chen Meian Email: chenmeian@igdp.cn
Copy Editors: Heather Xu, Diego Montero
Design and Layout: Bao Linjie

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Contact:

Tel：86-10-8532 3096
Fax：86-10-8532 2632
Email：igdpoffice@igdp.cn
Website：www.igdp.cn
Add：6-2-62, Jianguo Foreign Diplomatic Apartments, No. 1 Xiushui Street, Chaoyang District, Beijing, China