Strategies for Coordinated Reduction of Pollution and Greenhouse Gas Emissions from Animal Manure

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China's commitment to peaking its carbon dioxide emissions before 2030 and achieving carbon neutrality by 2060 is a significant and well-conceived strategic decision made by the central government. It concerns the sustainable development of China and the building of a community with a shared future for mankind. Emission reduction and carbon sequestration in animal husbandry is a crucial approach to achieve carbon peak and neutrality and enjoys profound research potential. Based on analyzing the current status, trends of greenhouse gas (GHG) emissions and relevant policies relevant to animal manure management at home and abroad, the recent development of animal husbandry and recycling utilization of animal manure in China, the report proposes policy suggestions such as improving manure storage and treatment, science-based monitoring and evaluation of greenhouse emissions in the livestock sector, and facilitating the access of animal husbandry to the carbon trading market, to provide support for the policies and actions on emission reduction and carbon sequestration in the agricultural sector.

I. Overview of animal manure treatment and utilization in China

In the 13th Five-Year Plan period, the central government has set great store by the recycling utilization of animal manure and made huge strides in the green development of the livestock sector. Animal manure in 585 major animal-farming counties has been recycled and manure treatment facilities have been established in 279,000 large-scale animal farms. About 75% of animal manure across the country has been comprehensively utilized while 95% of large-scale animal farms have been equipped with manure recycling equipment. A remarkable achievement has been made in pollution reduction and improvement of the animal farming environment. According to

the *Report on the 2nd National Census of Pollution Sources,* the chemical oxygen demand (COD), total emissions of nitrogen and phosphorous dropped by 21.1%, 41.8%, and 25.4% respectively from 2007 to 2017.

However, the integration of crop production with animal husbandry has been hindered by lack of standardization on animal manure treatment and utilization, lack of facilities for manure land application, including the facilities for manure fertilizing, injection machines. Meanwhile, no regulations are in place for GHG emission reduction in animal husbandry. Currently, the priority is put on the recycling of animal manure and water pollution control. GHG emissions have not drawn due attention. It is imperative to integrate crop production with animal husbandry, increase the efficiency of manure re-utilization, decrease nutrient loss and cut pollution and GHG emissions in a coordinated manner, and in particular decrease methane (CH_4) emissions during manure treatment and utilization.

II. Overseas situation and policies on GHG mitigation of animal manure management

Animal production is one of a major source of GHG emissions. The uncertainty of total emissions from the livestock sector is largely due to the different accounting boundaries (e.g. included or excluded GHG emissions from feed crop cultivation in the accounting boundary). According to the report of the Food and Agriculture Organization of the United Nations (FAO), the emissions of the animal husbandry sector amounted to 4.3 billion metric tons of CO_2 equivalent (CO_2e). The emissions from the livestock supply chain would be 8 billion if emissions from feed crop production were considered, of which CH_4 emissions from enteric fermentation accounted for 44% at a level of 3.5 billion ton CO_2e. Feed crop production is the second-largest source, which emitted 3.3 billion tons CO_2e, or 41% of the total emissions. Manure management generated 800 million tons or 10% of the total. The emissions from energy consumption for processing were equivalent to 400 million tons CO_2e, which took up a share of 5% of the total.

According to the report issued by the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) in September 2019, 192 Parties to the UNFCCC submitted their National Determined Contributions (NDCs) reports, 92 of which touched upon the emissions in the livestock sector. At the 26th Conference of the Parties of UNFCCC (COP26) in 2021, the United States and European Union launched the Global Methane Pledge, which was then joined by over 110 countries. Participants joining the Pledge agree to take voluntary actions to contribute to a collective effort to reduce global methane emissions at least 30 percent from 2020 levels by 2030. Participants also commit to moving towards using the highest tier IPCC good practice inventory methodologies to continuously improve the accuracy, transparency, consistency, comparability, and completeness of national greenhouse gas inventory reporting under the UNFCCC and Paris Agreement.

Figure 1 shows the GHG emissions from animal manure management in major developed economies (excluded emissions from feed crop production). Since 1990, all major developed economies apart from the U.S. have witnessed a downturn in

emissions from livestock.

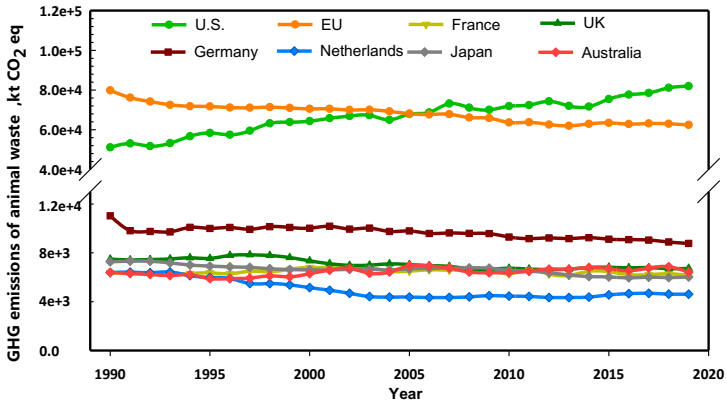

Figure 1. GHG emissions of animal manure major developed economies

The practices adopted by major developed economies are as follows:

A. EU: The overall methane emissions from EU agriculture have fallen by approximately 22% since 1990, mainly due to a reduction in ruminant livestock population. However, in the past 5 years, the livestock population has increased again, leading to a slight upturn in methane emissions in that period. While ensuring the livelihood and sustainable business opportunities for farmers, the EU will pursue sustainable production and methane emission reduction through innovation and technology on the one hand and by more sustainable diets on the other hand. As stated in the *EU strategy to Reduce Methane Emissions* in 2020, the EU pledged to take 5 actions to cut methane emissions in the agricultural sector, including setting up an expert group to analyze life-cycle methane emissions metrics, encouraging carbon-balance calculations at the farm level, promoting the uptake of mitigation technologies through the Common Agricultural Policy Strategic Plans, and conducting targeted research that effectively leads to methane emission reductions.

B. U.S.: CH_4 represents about 10% of U.S. greenhouse emissions. Agriculture, energy, and landfill are 3 major contributors to methane emissions, of which 37% comes from the agricultural sector. According to the *U.S. Methane Emissions Reduction Action Plan* issued in October 2021, multiple departments including the Department of Agriculture (USDA) is pursuing multiple workstreams to reduce methane emissions from the agricultural sector: (a) Adopting alternative manure management systems and other methane-reducing practices, and supporting anaerobic digester projects, the Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Program; (b) Expanding on-farm generation and use of renewable energy and establishing an Interagency Biogas Opportunities Task Force that will provide recommendations on policy and technological opportunities; (c) Developing a climate-smart agricultural commodities partnership initiative and putting forward new metrics and procedures to ensure reliability, effectiveness, and

transparency in certifying climate-benefitting practices; (d) Increased investments in agricultural methane quantification and related innovations;

C. **Germany**: The *Climate Action Programme 2030* endorsed by Germany in 2019 specified 10 measures for emission reduction and carbon sequestration in agriculture, manure related measures including encouraging the use of biogas for generating energy from livestock manure and agricultural residues, and gastight storage of digestate residues; increasing energy efficiency and the use of renewable energy in agricultural production. Germany intends to raise the share of farm manure (liquid and solid) in biogas plants to 30% of manure produced by 2030, and subsidize the power generation of small and medium-sized farms that use animal manure as the main raw material for fermentation and produce biogas for power generation.

III. Overview of GHG emissions of manure management and emission reduction measures in China

1. Briefing of emissions

According to the *IPCC Guidelines for National Greenhouse Gas Inventories*, CH_4 and nitrous oxide (N_2O) are the two GHG gases emitted from the manure management process. China's *National Greenhouse Gas Inventories* demonstrated that the emissions from livestock manure management were 138 million tons CO_2e in 2014, 40% of the emission of the animal production sector. This included 66 million ton CO_2e of CH_4, of which swine manure became the top contributor. Swine manure emitted a total of 1.948 million tons of CH_4, accounting for 63.9% of the total manure emission. Cattle manure shared the emissions of 14.6%. The N_2O emissions totaled 7200 tons CO_2e, of which 29.5% came from swine manure which is the largest source of N_2O emissions. It is followed by poultry manure and beef cattle manure, whose shares constituted 18.3% and 11.7%, respectively.

2. Technological advancement

China has stepped up support in R&D on pollution and carbon control technology in animal farming under the guidance of the national strategy "green mountains are gold mountains". The 12th Five-Year Plan period witnessed the launch of the specialized national project for public welfare in Agriculture – "R&D and demonstration of key technology on low-carbon, energy-saving and emission reduction for major animal production system". During the 13th Five-Year Plan period, seven national key R&D projects were targeted at the recycling of animal manure area, including "new technology and products for safe treatment and recycling of animal manure", "technology and smart control facilities for aerobic fermentation of agricultural waste", "technology and equipment sets for anaerobic fermentation and recycling of agricultural waste", "mechanism for recycling of agricultural waste", "regulatory system for bio-degradation and resource conversion of animal waste", as well as other demonstration projects. Innovative studies have been conducted on factors affecting recycling and utilization of animal manure, aerobic treatment and anaerobic

fermentation, removal of typical pollutants in animal manure, and recycling-related technology and modes, thus contributing to the technical advances of recycling of animal manure. However, no projects have been supported on synergies between GHG emission reduction and pollution control, the emission and reduction mechanism for GHG emissions of animal manure, or key technologies for emission reduction. It is imperative to work on specialized projects to underpin the realization of GHG reduction and increase of carbon sinks in the agricultural sector.

3. Relevant policies and measures

China issued work plans on emission reduction during the 12th and 13th Five-Year Plan periods to further identify the priorities of emission reduction in the livestock sector. In December **2011**, the State Council released the *Work Plan on Emission Reduction during the 12th Five-Year Plan Period*, underlining the need to enhance comprehensive utilization of animal and urban wastes and control the emission of methane and other GHGs. According to China's *Nationally Determined Contributions* submitted to the UNFCCC in **2015**, China proposed to establish a circular agricultural system for the comprehensive utilization of animal manure and enhanced carbon sequestration capacity of the soil. In October **2016**, the State Council published the *Work Plan on Emission Reduction during the 13th Five-Year Plan Period*. The country will control GHG emissions in animal farming, breed high-yield and low-emission varieties, build large-and-medium scale biogas facilities at animal farms in light of local conditions, develop standard-based and large-scale animal farming, and work for comprehensive utilization of animal manure. By 2020, more than 75% of large-scale farms should be equipped with manure recycling facilities. The construction of facilities for the utilization of manure has laid a foundation for manure GHG reduction.

The *14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives through the Year 2035* released in March **2021** indicated the necessity of better controlling methane, hydrofluorocarbons (HFCs), Perfluorinated Chemicals (PFCs), and other GHGs, and enhancing the adaptation and increase the resilience to climate change in the agricultural sector. In November 2021, China and the U.S. jointly presented the *China-US Joint Glasgow Declaration on Enhancing Climate Action in the 2020s*, which noted the role of incentives and programs in cutting methane emissions in agriculture.

4. Case study

Building upon the research on manure utilization and emission reduction, more mature technical models have been developed to enhance the comprehensive utilization of manure through manure biogas power generation and carbon trading. One typical case is as follows:

CDM project for chicken manure biogas power generation of Shandong Minhe Animal Husbandry Co., Ltd

Located in Penglai City, Shandong Province, Shandong Minhe Animal Husbandry Co., Ltd has an average stock of 4 million chickens. The company has invested 60 million

RMB in the biogas power generation project. The project has 8 anaerobic digesters, with a total volume of 33000 cubic meters, which can process more than 800 tons of manure, producing 30,000 cubic meters of biogas, and generating 60,000 kWh of electricity per day and 22 million kWh of electricity per year. The project has been inefficient and steady operation for 12 years in a row.

The project achieved on-grid power generation in February 2009 and was approved by the UNFCCC as a CDM project (Clean Development Mechanism) in April 2009. With an annual GHG emission reduction of around 80,000 tons of CO_2e which was verified by an international third-party agency and issued by the UNFCCC. The project realized carbon emissions trading with the World Bank. In addition to the annual revenue of 14 million RMB from power generation, the project can also earn more than 7 million RMB from carbon emission reduction. Carbon trading with the World Bank has extended the function of manure biogas treatment and diversified the source of farm revenue, making carbon emission reduction the main profit source of Minhe's biogas power generation project. The CDM project for chicken manure biogas power generation of Shandong Minhe Animal Husbandry Co., Ltd is not only the first mega biogas project in China but also the largest livestock manure biogas power generation project in the world at that time. It serves as a successful example for the commercialized operation of China's manure biogas power generation project through CDM.

IV. Opportunities and challenges

With the rapid upscaling of China's livestock industry, large-scale farmers face multiple challenges including a large quantity of manure, longer duration of storage and processing, etc. By comparing GHG emission data of the livestock sector in different years, it is found that GHG emissions from manure management in China show a gradually increasing trend. There are two reasons. First, the increase of large-scale livestock farming has led to the large quantity of manure in one farm, which thus results in the growth of GHG emissions in manure management. Second, there exist strict standards for pollution control and manure resource utilization in livestock and poultry farms. Although the direct discharge of liquid manure from large-scale farms has been prohibited, and liquid manure processing is becoming more and more standardized. The proportion of large-scale farms that use inhouse deep pit manure storage and cleaning system is increasing. The liquid manure management system can further increase methane emissions.

With China's urbanization and people’s living standards keep improving, the consumption demand for livestock products in China will continue to increase in the next decade. Therefore, the major task for the livestock sector remains to enhance production capacity to meet the people's growing consumer demand. To contribute to carbon peak and carbon neutrality, more attention should be paid to improving the production efficiency of the livestock sector for a sufficient supply of animal products, and more cost-effective and practical technologies should be adopted to enhance coordination between GHG emission reduction and high-quality development of the

livestock sector.

The high-quality development of the livestock sector will help accelerate the transformation of animal production, and upscale livestock and poultry breeding. In the meantime, advances will be made in breeding, disease control, infrastructure, and equipment. Feeding and reproductive efficiency, production performance will also be further improved. When the output of animal products remains the same level, the stock and market animal population will show a downward trend due to higher livestock performance, the quantity of manure will gradually decrease steadily. At the same time, continuous innovation in manure utilization rate and efficiency has laid a solid foundation for pollution control and carbon reduction. However, China's manure utilization and GHG emission reduction still face the following challenges.

First, not an advanced livestock production system. Compared with developed countries, China has a larger amount of animal farms and those farms are in the process of transformation and upgrade. There are various production systems methods, relatively extensive, and less integration between crop farming and animal production. Therefore, an obvious gap exists in livestock production between China and developed countries. Due to no quantity reduction requirement on GHG and ammonia emission in manure management in the past, more efforts are required to reduce these emissions in the future.

Second, difficulty in balancing the environmental and economic benefits. In 2016, It is estimated that China's total GHG emissions from manure management reached 141 million tons of CO_2e, and the contributions to the total national GHG emissions continue to increase. Efforts are needed to further improve manure management and reduce GHG emissions. This will inevitably increase infrastructure investment and operational cost, which means high input, low output, or even no benefit from the additional investment. Therefore, the profit of livestock farms will decrease. It poses more difficulties in mobilizing the enthusiasm of farms (households) to reduce pollution and GHG emissions if without corresponding compensation or subsidies.

Third, lack of monitoring and assessment system on GHG emissions and their mitigation. China has not yet put in place a GHG emission monitoring network for manure management. The main GHG emission factors are obtained through limited investigation and then calculated according to the methodology recommended by the IPCC guidelines. Although the calculated emission factors have been verified by experiments, there are still uncertainties due to various manure management systems in different regions and different livestock systems and limited on-site monitoring of GHG emissions.

V. Policy recommendations for methane mitigation

As China strives to achieve a carbon dioxide peak by 2030 and carbon neutrality by 2060, green and low-carbon circular development become the solution to addressing resource and environmental constraints and realizing high-quality growth of the livestock sector. Therefore, based on the current status of China's livestock sector, we

suggest that priorities should be given to the promotion of animal production and improvement of manure management, acceleration of technology innovation, and adoption and scale-up of technologies and measures to reduce GHG emissions. The policy supports should also be strengthened. The goals are to achieve a manure utilization rate of 80% by 2025 and 85% by 2030, respectively. The utilization of manure as energy and fertilizers will play an increasingly effective role in pollution control and GHG mitigation, which will contribute to green and low-carbon circular development of the livestock sector and reduction of methane and other GHGs.

Major recommendations are as follows:

First, speeding up the transformation of the livestock production system. Vigorous efforts should be made to foster new businesses, develop intensive production based on local conditions, and encourage small and medium-sized farms (households) to improve infrastructure, expand the scale and increase the proportion of large-scale production. A standardized production system should be scaled up, and guidance should be provided to farms (households) in farm design and construction, to make livestock farming more standardized, automatic, and smart, and improve manure collection and treatment efficiency.

Second, advancing green and low-carbon manure recycling utilization. Continued efforts should be made to implement the countywide program for manure resource utilization and the national program for manure utilization in the integration of crop production and animal farming. Cost-effective manure treatment facilities should be developed. Technologies including closed storage and composting should be extended to reduce GHG and ammonia emissions. Social capital investment in biogas production using manure as the main raw material should be encouraged to boost biogas production efficiency and methane recovery rate.

Third, conducting science-based monitoring and assessment of GHG emissions from the livestock sector. A GHG monitoring network for manure management should be established to regularly monitor GHG emissions from livestock farming. Efforts should be made to improve the calculation methods, tools, and reporting so that a system for carbon footprint calculation and mitigation decision-making can be developed to help farmers calculate their carbon footprint, and evaluate the effects and benefits of mitigation measures. Provide guidance to farmers on the adoption of more effective measures to mitigate GHG emissions.

Fourth, encouraging livestock to participate in the carbon trading market. It is advised that the emission reduction from manure recycling utilization projects can be traded in the domestic carbon trading market in due course, develop and consolidate baseline and monitoring methodologies for GHG emission reduction in large-scale farms, and set reasonable allocation quota for the livestock sector in national carbon trading market. It is recommended that demonstrate the mode of carbon trading on manure utilization projects for different animal farming and different manure utilization system should be carried out to make full use of the role of the carbon market in resource allocation.

VI . Supporting the formulation of manure utilization related contents in the 14th Five-Year Plan and updated NDC

The utilization of livestock manure is the key to the prevention and control of agricultural non-point source pollution and promotion of green and low-carbon agricultural development in China. The research team of the project actively participated in the planning and expert consultation related to livestock manure utilization, shared the outputs of the project, and provided support for the preparation of manure utilization related contents in the documents of 14th Five-Year Plan and updated NDC.

As the utilization level of livestock manure returning to the field in China is still low and cannot fully meet the requirements of green and low-carbon development of agriculture in China, the project team participated in the preparation of "The 14th Five-year Construction Plan on Manure Utilization to Promote Combination of Crop and Livestock Production". The plan aims to accelerate resource utilization of livestock manure, and build models for the integration of crop and livestock production. The Plan include four key tasks: Promote the manure land application and improve the quality of cultivated land; Improve the level of facilities and equipment and promote the efficiency of manure utilization; Strengthen scientific and technological innovation capabilities and improve support services; Improve the market operation mechanism, enhance the ability of sustainable development. By 2025, comprehensive utilization rate of livestock manure at national level will reach 80%, and provide support for more than 250 demonstration counties to promote the construction of livestock manure treatment facilities and apply manure to croplands. The proportion of replacement of chemical fertilizers with manure in the demonstration counties will reach more than 30%, the content of soil organic matter will be significantly increased, and the effect of manure utilization on emission reduction and carbon sequestration will be remarkable.

Manure utilization is an important part of vigorously promoting emission reduction and efficiency improvement in agricultural sector in China's updated NDC. China has accelerated the resource utilization of livestock manure, replaced chemical fertilizers with organic fertilizers，less consumption and more efficient use of chemical fertilizers and pesticides, in order to reduce GHG emissions from agricultural sector and improve soil carbon sequestration, with a view to green and low-carbon agricultural development. As of 2019, comprehensive utilization rate of livestock and poultry manure accounted for 75% at national level. The research team actively participated in the formulation of updated NDCs. As consultant experts, two members of the project team participated in two rounds of document modification, proposed the strategy and action countermeasures suggestions on GHG mitigation and carbon sequestration in agricultural sector including manure management, which supported the formulation of China's updated NDC. "China's achievements, New Goals and New Measures for Nationally Determined Contributions" clearly proposes to vigorously promote emission reduction and efficiency improvement in agricultural sector, to reduce greenhouse gas emissions from livestock sector by promoting livestock productivity and improving ways of the treatment and utilization of animal manure.